DEVELOPMENT OF PRINTED LOG-PERIODIC PLANAR ANTENNA USING FRACTAL KOCHGEOMETRY

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Abstract

Digital terrestrial television (TV) broadcasting has been adopted in the Philippines with the Digital Switch last 2017. TV viewers can now experience the digital picture and sound through free-to-air TV signals in the household. Nevertheless, the quality of TV pictures and sound studies on digital TV has not been realized because it requires the International Telecommunication Union (ITU) assessment (ITU-R BT.500-13) reference. This paper aimed to develop a printed log-periodic planar antenna where the antenna arrays were based on Fractal Koch geometry and determine the digital picture and sound quality received from a digital television box. The calculated Fractal Koch geometry was applied to the printed circuit board, and circuitry was assembled to evaluate TV picture and sound quality. Ten (10) random TV viewers participated in the subjective assessment using ITU-R BT.500-13 evaluation procedure for sound and picture quality laboratory set-up. Mean and standard deviation was used to measure the digital TV signal's picture and sound quality level. Based on the results, the overall mean scores of the TV picture and sound quality were 4.59 and 4.68 with the standard deviation values of 0.58 and 0.48, interpreted as excellent respectively. TV picture and sound quality were imperceptible to the TV viewers. FractalKoch Geometry is a novel method for reducing antenna array length in the development of log-periodic printed planar antennas that receive a digital television signal, allowing TV viewers to experience smoother images and better sound quality from digital television broadcasts.

Keywords: *digital television, log-periodic printed planar antenna, Fractal Koch Geometry*

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Introduction

According to several patents, the log-periodic antenna design was suitable for digital TV antenna reception in the Ultra High Frequency (UHF) band (DuHamel and Ore, 1957; Huang and Chen, 2002; Eckwielen and Hagen, 2011). The miniaturization of the stacked multilayered PCB and length reduction techniques will provide coverage comparable to that of the traditional UHF stacked log-periodic antenna, which is long, heavy, and expensive (Anagnostou et al., 2008).

Enhancing digital TV images and sound was a challenge for antenna designers because attenuation caused by electronic components varies depending on the specific UHF band of TV channels available to television viewers and the location of the broadcast station's digital TV antenna transmitter. To address this problem, the researcher designed a bandpass filter based on the channel frequencyand resistor-capacitor circuitry fed to the balanced-unbalanced (balun) antenna component, causing the received signal to attenuate. The proposed miniaturization and bandpass filter design was hypothesized to reduce attenuation and improve TV picture and sound quality in the UHF band.

Conceptual Framework of the Study

Figure 1 shows the Input-Process-Output model. The input from the TV Station transmitter receives the TV signal in the antenna where Fractal Koch Geometry reduced the TV signal composed of the picture and sound signal decodedin ISDB-T Digital Box. Then, video and audio cables such as (RCA and HDMI) are interfaced between ISDB-T Digibox and Digital or Analog Television toproduce quality TV pictures and sound.

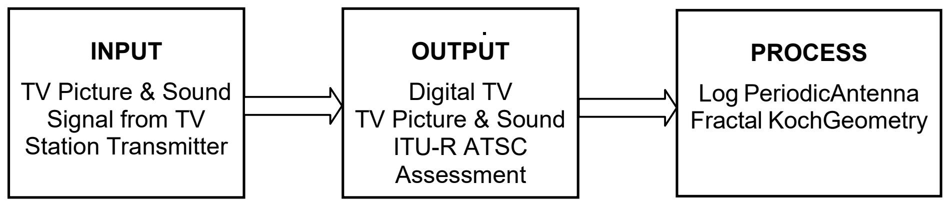

Figure 1. *The Conceptual Framework of the Study*

Materials and Methods

The study used a descriptive and developmental method of research to design,construct, and assess the qualityof TV pictures and sound received from the log-periodic printed antenna.

The Log-periodic printed planar antenna has the following parts:

1. Multilayered Printed Circuit Board (PCB) with Log-Periodic Dipole Array elements printed on each PCB;
2. Bandpass filter circuit to smoothen out TV signals receive due to multipath and interference; and,
3. Matching Transformer or balun (75 ohms) connected to the antenna input. Fractal Koch Geometry Design.

The researcher calculated a log-periodic antenna design based on the NTC-recommended 512 MHz and 698 MHz frequencies for optimal TV reception. On each stacked PCB, the dielectric material was FR4 PCB with a 0.85 mm spacing. As a result, the antenna element arrays were computed using the methods described by Balanis (2005) and Karim et al. (2010). A microstrip patch antenna with fractal snowflake and Kochcurve geometry meets the wireless industry's miniaturization requirements.The proposed method was to combine the Fractal snowflakeand the Koch curve to create a novel “Fractal Koch Geometry” that was hypothesized to perform similarly to a typical log-periodic antenna used for outdoor TV reception.

A bandpass filter (BPF) is a device that allows frequencies within a specific range to pass while rejecting or attenuating frequencies beyond that range. The bandpass frequency selectivity of a BPF is an important multifunctional integrated component that provides both balanced conversions of a balun and bandpass frequency selectivity of a BPF at the same time, reducing the cost and size of the functional block in modern compact wireless communication systems (Zhang et al., 2018). The resistor and capacitor values were calculated by the researcher using the RC bandpass circuit, which can be adjusted depending on the frequency band, which is between 512 and 698 MHz.

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Design Construction and Test of Antenna

The steps in the design construction and test of the printed antenna are under a nondisclosure agreement recently made in the drafting of a utility model for the design. General procedures were discussed to ensure intellectual property as disclosed in the procedure shown in Figure 2.

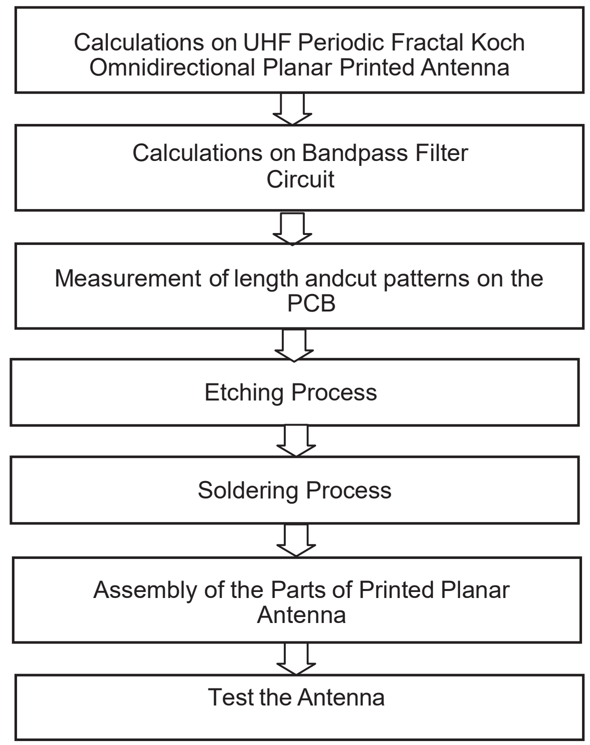

Figure 2. *Design Construction and Test of Antenna*

Evaluation Procedure

In the study, the ITU-R BT.500-11 and BS.1284-1 were used to assess the quality of television pictures and sound quality respectively. Ten (10) observers or respondents assessed the performance of the TV antenna in terms of coverage characteristics, service and channel characteristics, and sound quality in terms of spatial impression, stereo impression, transparency, sound balance, timbre, and freedom from noise and distortion.

After that, the results were computed and analyzed for statistical interpretation (ITU Radiocommunication Bureau (BR), 2002; ITU Radiocommunication Bureau (BR), 2004).

Research Instrument

The Questionnaire for Printed Log-Periodic Planar Antenna Using Fractal Koch Geometry is based on the evaluation related to the assessment of television picture and sound quality using the ITU-R Field Test Plan instrument. The ITU-R recommendations are approved by the ITU Member States developed by experts from administrations, operators, industry, and other organizations dealing with radio communication matters worldwide. They enjoy a high reputation and are implemented worldwide (ITU Radiocommunication Bureau (BR), 2012).

The ten (10) technical experts in TV communications were asked to indicate the level of performance of the log-periodic printed planar antenna using Fractal Koch Geometry in terms of television picture quality,sound quality, and the overall sound image impression and interaction between the parameters by responding to a five-point scale with the following values: Excellent, 4.20– 5.00; Good, 3.40 – 4.19; Fair, 2.60 – 3.39; Poor, 1.80 – 2.59; and Bad, 1.0 – 1.79.

Statistical Tools Used

Mean was used to determine the quality of the antenna and standard deviation to validate the similarity of their responses.

Parameters of Analysis

The following were the parameters used for the analysis of the log-periodic printed planar antenna using Fractal Koch Geometry: coverage characteristic, service, and channel characteristic for television picture quality; and spatial impression, stereo impression, transparency, sound balance, timbre, freedom from noise, and distortion for television sound quality.

Results and Discussion

The results showed that the developed log-periodic printed planar antenna could receive digital television signals.

A Fractal Koch Geometry integration with log-periodic printed planar antenna can be made with length reductions on each multi-layered printed antenna array element and a bandpass filter for Ultra High Frequency (UHF) band 512 MHz to 698 MHz. Figure 3a shows the Log-Periodic Printed Planar Antenna with Fractal Koch Geometry stacked into a multi-layered printed circuit board (PCB) with an appropriate distance to reduce attenuation. Unlike a typical TV antenna array, shown in Figure 3b,the antenna arrays in this antenna were aluminum arrays as in a typical antenna.

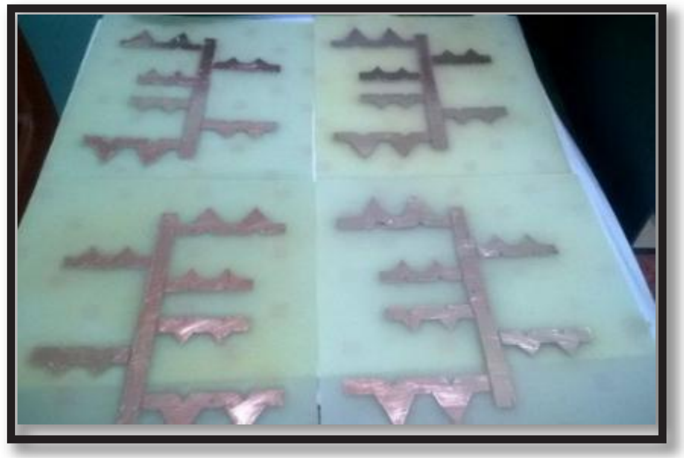

Figure 3a. *Finished Printed Planar Antenna*

Figure 3b. *Typical Log-Periodic Dipole Antenna [BAZ Antennas 2012]*

In assessing the TV picture signal received from the antenna, the coverage characteristics, service or receivability, and channel characteristics were included.

Table 1

Mean scores on Quality of TV Picture

Item or Questions Raised	M	SD	Verbal Interpretation
1. Coverage characteristics			
ABSCBN	4.47	0.62	Excellent
SPORTS+ACTION	4.87	0.35	Excellent
CINEMO	4.67	0.49	Excellent
YEY!	4.53	0.63	Excellent
KNOWLEDGE CHANNEL	4.63	0.62	Excellent
DZMM TELERADYO	4.33	0.70	Excellent
Average	4.58	0.60	Excellent
2. Service (Receivability)			
Modulated and Demodulated Statistics	4.60	0.52	Excellent
Signal level variations	4.60	0.52	Excellent
Multipath measurements	4.63	0.59	Excellent
Average	4.62	0.56	Excellent
3. Channel Characteristics			
Multipath	4.50	0.71	Excellent
Field Strength	4.50	0.53	Excellent
Impulse Noise	4.70	0.48	Excellent
Average	4.57	0.57	Excellent
Overall Mean Score	4.59	0.58	Excellent

Score and Interpretation: 1-Bad; 2-Poor; 3-Fair; 4-Good; 5-Excellent (ITU Radiocommunication Bureau (BR), 2002*).*

Table 1 shows the mean score on the assessment of the quality of the TV picture. The overall obtained mean score was 4.59 with an overall standard deviation of 0.58,interpreted as excellent.

In terms of coverage characteristics, the highest obtained mean score was 4.87 with a standard deviation of 0.35, interpreted as excellent on the item of the sports+action. On the other hand, the lowest attained mean score was 4.33 with a standard deviation of 0.70, interpreted as excellent on the item of the DZMM Teleradyo.

In terms of service or receivability, the highest obtained mean score was 4.63 with a standard deviation of 0.69, interpreted as excellent on the item multipath measurements.On the contrary, the lowest mean score was 4.60 with a standard deviation of 0.52, interpreted as excellent on both modulated and demodulated statistics and signal level variations.

In terms of channel characteristics, the highest obtained mean score was 4.70 with a standard deviation of 0.48, interpreted as excellent on the item impulse noise. Likewise, the lowest mean score was 4.50 with a standard deviation of 0.71, interpreted as excellent on the item multipath.

In addition, Table 1 discusses the average of the mean scores on the quality of TV pictures.The highest obtained mean score was 4.62 with a standard deviation of 0.56, interpreted as excellent on the item service. Likewise, the lowest yielded mean score was 4.57 with a standard deviation of 0.57, interpreted as excellent on the item channel characteristics.

The findings revealed excellent service or receivability, which implies that the antenna can receive quality TV pictures in the urban environment. In a study conducted by Caluyo and Dela Cruz (2012), the installation of an additional bay panel antenna is recommended to increase service coverage of the TV transmitter not only within the city but also in rural environments. Hence, further studies on broadcast service can be pilot tested in rural locations where TV signal is inherent.

In assessing the television sound quality of the received signal from the antenna,the following categories were considered: spatial impression, stereo impression, transparency, sound balance, timbre, and freedom from noise and distortion.

Table 2 shows the mean scores on the assessment on the quality of TV sound. The overall obtained mean score was 4.68 with an overall standard deviation of 0.48,interpreted as excellent.

In terms of spatial impression, the highest attained mean score was 4.70 with a standard deviation of 0.48, interpreted as excellent on both items, homogeneity of spatial sound, and apparent room size, respectively. Conversely, the lowest obtained mean score was 4.50 with a standard deviation of 0.71, interpreted excellent on the items, acoustic balance, depth perspective, and sound color of reverberation.

In the aspect of transparency, the highest obtained mean score was 4.90 with a standard deviation of 0.32, interpreted as excellent on the item intelligibility. On the other hand, thelowest attained mean score was 4.80 with a standard deviation of 0.42, interpreted as excellent on the items, sound source definition, and time definition.

In the area of sound balance, the obtained mean scores were 4.70 with a standard deviationof 0.48, interpreted as excellent on the items, loudness balance, and dynamic range.

In terms of timbre, the highest obtained mean score was 4.80 with a standard deviation of 0.42, interpreted as excellent on the item sound attack. Likewise, the lowest attained mean score was 4.70 with a standard deviation of 0.48, interpreted as excellent on the item sound color.

Table 2

Mean Scores on Quality of TV Sound

Item or Questions Raised	M	SD	Verbal Interpretation
1. Spatial impression			
Homogeneity of spatial sound	4.70	0.48	Excellent
Reverberance	4.60	0.52	Excellent
Acoustic balance	4.50	0.71	Excellent
Apparent room size	4.70	0.48	Excellent
Depth perspective	4.50	0.71	Excellent
Sound color of reverberation	4.50	0.71	Excellent
Average	4.58	0.59	Excellent
2. Stereo impression			
Directional balance	4.60	0.52	Excellent
Stability	4.70	0.48	Excellent
Sound image width	4.70	0.67	Excellent
Location accuracy	4.70	0.48	Excellent
Average	4.68	0.53	Excellent
3. Transparency			
Sound source definition	4.80	0.42	Excellent
Time definition	4.80	0.42	Excellent
Intelligibility	4.90	0.32	Excellent
Average	4.83	0.38	Excellent
4. Sound balance			
Loudness balance	4.70	0.48	Excellent
Dynamic range	4.70	0.48	Excellent
Average	4.70	0.47	Excellent
5. Timbre			
Sound color	4.70	0.48	Excellent
Sound attack	4.80	0.42	Excellent
Average	4.75	0.44	Excellent
6. Freedom from noise and distortion	*4.70*	*0.48*	Excellent
Overall Mean Score	4.68	0.48	Excellent

Score and Interpretation: 1-Bad; 2-Poor; 3-Fair; 4-Good; 5-Excellent (ITU Radiocommunication Bureau (BR), 2004).

Freedom from noise and distortion obtained a mean score of 4.70 with a standard deviation of 0.48, interpreted as excellent. In addition, Table 2 discusses the average of the mean scores on the quality of TV sound. As categorized in terms of TV sound quality, the highest obtained mean score was 4.83 with a standard deviation of 0.38, interpreted as excellent on the item transparency. On the other hand, the lowest obtained mean score was 4.58 and a standard deviation of 0.59, interpreted as excellent on the item spatial impression.

The findings imply excellent sound image impression due to passive RF enhancers like filters (RC & LC) used in the antenna, as confirmed by the study of Eckwielen and Hagen(2011). Additional filter coupling techniques were also recommended inthe study conducted by Huang and Chen (2002), which smoothens the received digital television signals from the antenna.

The picture quality of the log-periodic printed planar antenna in terms of coverage characteristics, service or receivability, and channel characteristics was excellent. The sound quality of the log-periodic printed planar antenna in terms of spatial impression, stereo impression, transparency, sound balance, timbre, and freedom from noise and distortion was excellent. The overall obtained mean score on the assessment of the quality of the TV picture and sound signal received from the log-periodic printed planar antenna using Fractal Koch Geometry was excellent.

Conclusions

In conclusion, Fractal Koch Geometry is a viable length reduction method for designing and developing a log-periodic printed planar antenna. The multi-stacked PCB layer approach and bandpass filter design were also applied to enhance TV pictures and sound quality. Overall subjective assessment results based on ITU-R BT.500-13 were excellent in the TV pictures and sound quality, specifically on coverage characteristic and transparency. TV picture and sound quality were imperceptible to the TV viewers. Fractal Koch Geometry is a novel method for reducing antenna array length in developing log-periodic printed planar antennas that are suitable to receive a digital television signal, allowing TV viewers to experience smoother images and better sound quality digital television broadcasts.

The antenna may be used for portable and mobile TV reception. Further research is recommended for electromagnetic and radiation pattern simulation. The TV station should adjust transmitter settings for optimum digital TV broadcast in urban areas and rural locations in Negros Occidental.

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