Paper

# The Design and Applications of a Gap Noise Generator for Simulating Corona Discharge from Test Line


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In order to survey the radiation characteristics of pure line noise produced by corona discharge from overhead high voltage transmission lines, a disk type gap noise generator is manufactured. Disk size that decides capacitance between the noise generator and the ground is selected through preliminary indoor experiments and analysis by using charge simulation method. The field experiments are performed with the noise generator hung on the Kochang 765 kV full scale test line. As the results, the useful data that can be used to analysis the radiation characteristics of corona noises from transmission lines are obtained. Those data are the directivity of antenna toward the line, lateral profiles, frequency spectra, height pattern and so on.



**Keywords:** EMI, gap noise generator, noise current, lateral profile


## 1. Introduction

Noise generated from facilities in high-voltage equipment and overhead transmission lines may interfere television and radio receiving in adjacent areas. To set up a countermeasure that can suppress such noise at the step of construction, it was required to survey radiation characteristics of EMI (Electromagnetic Interference) especially around the transmission line where a large amount of noise is generated and measure the noise quantitatively. A Gap Noise Generator was used for the survey in this study. As capacitance of a line is artificially enlarged with a gap noise generator installed on the line, the line will be injected with a high noise current owing to the gap discharge within the gap noise generator though a low voltage applies the line. The gap noise generator, thus, can be used, in measuring line noise from an extra high voltage test line, for measuring only line noise except for unwanted noise from erosion connection parts of metal parts, insulators, hardware, etc.. It also enables to measure radiation characteristics made by the gap discharge itself. Gap noise generators have been used overseas in surveying characteristics of radio interference (RI) and television interference (TVI) by using the principal of gap discharge [(1)~(3)].

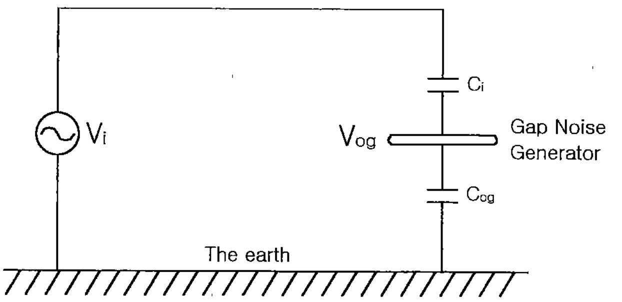
## 2. The Design and Manufacture of Gap Noise Generator

**2.1 Equivalent Circuit of Gap Noise Generator** The high frequency current ($I_{og}$) from a gap noise generator installed on the transmission line is proportional to its capacitance as shown in the Eq. (1). However, the high frequency induced voltage $V_{og}$ of an actual system cannot be analytically obtained from the Eq. (1).

$$I_{og} = j\omega C_{og} V_{og} = j(2\pi f) C_{og} V_{og} \cdots\cdots\cdots\cdots \quad (1)$$

Thus, to get $V_{og}$ herein, first obtain the mutual capacitance $C_{og}$, between the gap noise generator and earth which can be detected by a RI Meter, from a preliminary indoor experiment and then calculate size of the generator when it satisfies the $C_{og}$ in the full scale test line experiment. As the mutual capacitance $C_{og}$ between the gap noise generator and earth is varied by the geometric structure of adjacent transmission line, a system equation covering both the generator and transmission line should be employed to obtain the value. In the model in this study as transmission lines and gap noise generator are 3 dimensional geometric structures, in order to calculate 3-dimensional capacitance, it is required 3-dimensional transmission line modeling and gap noise generator modeling.

**2.2 Preliminary Indoor Experiment** A




$V_i$: High frequency voltage at transmission line
$V_{og}$: High frequency induced voltage of Gap Noise Generator
$C_i$: Mutual capacitance between transmission line and Gap Noise Generator
$C_{og}$: Mutual capacitance between the earth and Gap Noise Generator

Fig. 1. Equivalent circuit of gap noise generator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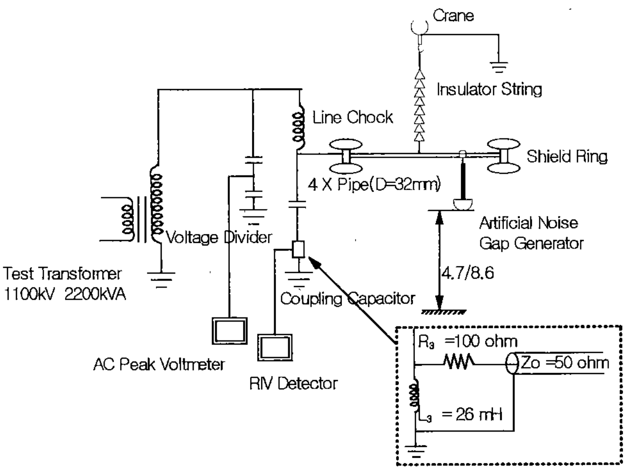



Fig. 2. Preliminary indoor experiment of disk type gap noise generator

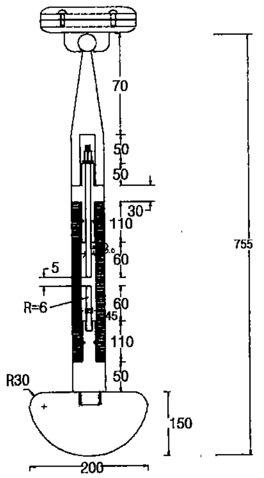



Fig. 3. Hemisphere-type gap noise generator used for preliminary performance experiment

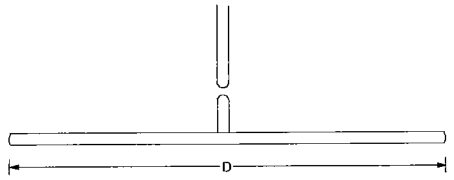



Fig. 4. Concept diagram of disk type gap noise generator

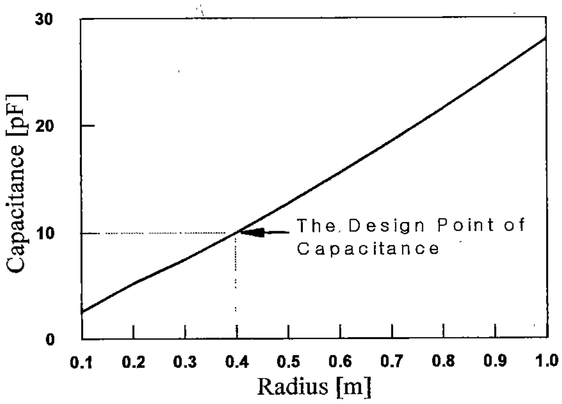



Fig. 5. Capacitance by disk size when gap noise generator is installed on the bottom phase of test line

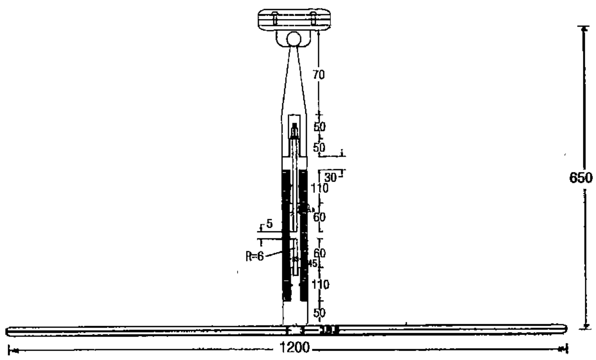



Fig. 6. Diagram of completed gap noise generator

preliminary indoor experiment is performed under standard NEMA 107-1987 and the outline of experiment circuit is illustrated in the Fig. 2. Test transformer applies voltage to artificial noise gap generator and the instrument measures RIV (Radio Influence Voltage) from discharge generated gap noise generator. To restrict the loss and do not disturb measuring data, the line choke is installed at the upside part of coupling capacitor. The gap noise generator is used in the indoor experiment as shown in the Fig. 3. In order to determine the optimal capacitance of gap noise generator, various tests are done in the indoor experiment.

### 2.3 Manufacture of Gap Noise Generator

Capacitance of the gap noise generator is calculated in order to survey radiation characteristics of transmission line by means of the Charge Simulation Method, and capacitance design reference of the gap noise generator to be tested on the full scale test line is set to 10 pF. The configuration of gap noise generator to be installed on the test line is determined to disk type in consideration of weight and difficulty of manufacture, shown in the Fig. 4.

In order to determine the size of disk that realizes the capacitance of 10 pF when the disk type generator is installed on the bottom phase of test line located 28 m above ground, capacitance is calculated for each size of disk as shown in the Fig. 5. As the result, at least 40 cm radius is necessary to assure 10 pF capacitance with disk type generators. On the basis of the capacitance obtained in the above calculation, 5 mm of space is given to the gap of gap noise generator to be installed on the full scale test line and a disk of 60 cm radius is made, to margin, of aluminum plate. The finally manufactured gap noise generator is illustrated in the Fig. 6.

## 3. Field Experiment under 765 kV Test Line

**3.1 Instrumentation System** Instrumentation system is installed in the vehicle as shown in the Fig. 7. In the vehicle, in addition, RI meter and TVI meter are mounted inside and an antenna master is installed on the ceiling to secure the antenna.

(1) Radio Interference system The Rhode & Schwarz EMI receiver, model ESHS 30, was used to

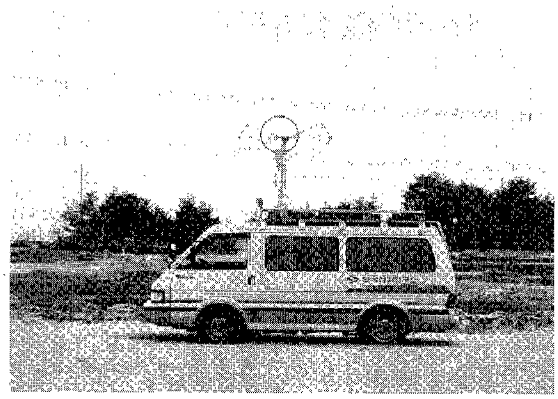


Fig. 7. Vehicle for measuring the noise of transmission line

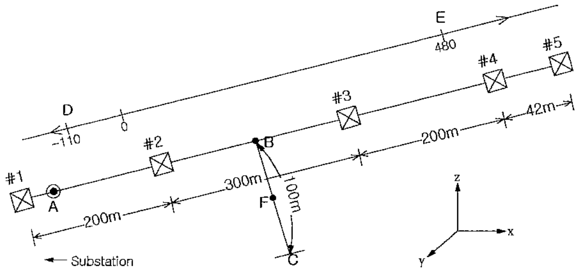



Fig. 8. Installing and measuring points of gap noise generator

monitor the quasi-peak (QP) levels of the RI sensed by active loop antenna, HFH2-Z2. This receiver and antenna conform to CISPR specifications. A monitoring frequency 475 kHz was chosen for all the measurements, this being a frequency that was relatively free of interference from radio broadcast signals and where background interference was the lowest. It is also quite close to the CISPR reference frequency of 0.5 MHz for measuring RI from overhead lines.

(2) Television Interference system The Rhode & Schwarz EMI test receiver, model ESVS 30, was used to monitor the QP levels of TVI detected by biconical antenna, HK-116. This receiver and antenna conform to CISPR specifications also. A monitoring frequency 75 MHz was chosen for all measurements.

**3.2 Installing and Measuring Points of Gap Noise Generator** Installing points and measuring points of the gap noise generator for the field experiment performed in Kochang 765 kV test field are shown in the Fig. 8.

- A: Points where gap noise generator is installed
- B–C: Points where lateral profile is measured
- D–E: Points where longitudinal profile is measured
- F: Points where horizontal pattern of line noise is measured

## 4. Test Results

Various experiments were performed with a gap noise generator installed at point A of bottom phase of test line as shown in the Fig. 9. A testing voltage should be selected between the initial discharge voltage of gap noise generator and the voltage which all the other equipment on the test line except the gap noise generator is free from corona. In this study, thus, 90 kV is selected as the testing voltage in consideration of the tap option of testing transformer.

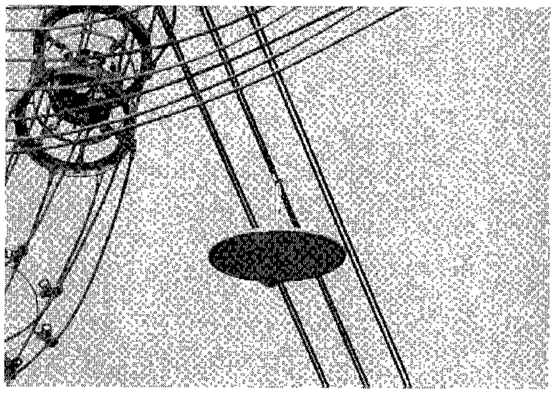


Fig. 9. Gap noise generator installed on test line

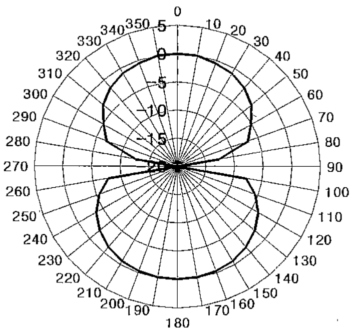



Fig. 10. Direction of receiving maximum radio noise

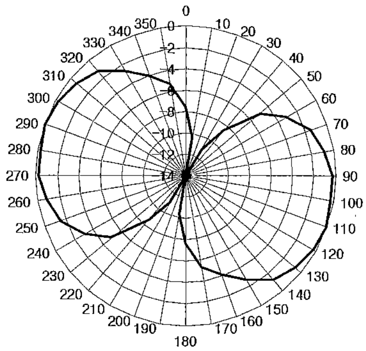



Fig. 11. Direction of receiving maximum television noise

**4.1 Direction of Receiving Maximum Radio Noise** For measuring lateral profile and longitudinal profile, depending on the measuring point the noise generated by the noise current injected to conductor from the gap noise generator may be differently measured owing to the influence of noise radiated from the gap noise generator itself directly.

So in order to survey the influence of these, the direction that antenna receives maximum noise from the line was measured at point F as shown in the Fig. 8. The measured direction is 0° for the line and 290° for the gap noise generator and the results are as shown in the Figs. 10 and 11.

It was proved that the maximum receiving direction is toward the line in the radio frequency bandwidth as shown in the Fig. 10. Thus, measuring noises from the line conductor can be free from the influence of noise radiated from the gap noise generator itself directly by setting the antenna in the direction of line while measuring lateral profile in radio frequency bandwidth. In the television bandwidth, however, as direct noise radiated from gap of the generator is larger than one from conductor. Thus it was verified that TVI is more affected by gap discharge such as insulator or hardware than noise from conductor itself in practice.

**4.2 Lateral Profile** The lateral profile of radio noise generated from the conductor of test line is measured while the measuring vehicle is moving from point B to C and the results are shown in the Fig. 12. It was proved that radio interference level is regularly reduced proportionally to the lateral distance from the line. In respect of television bandwidth, as TV interfere level by gap discharge is much more than one from line conductor, TVI lateral profile was surveyed at the point where the gap noise generator is installed and the results are as shown in the Fig. 13. Because television bandwidth frequency is more than dozens of MHz, it is found that TVI is reduced after repeatedly moving between maximum and minimum value, depending on line configuration and measuring frequency, by dozens of or hundreds of m several times [4].

**4.3 Frequency Spectra** When traveling-wave reaches a transition point such as line terminal, overhead line and cable, connection point of line and apparatus, etc. some of the traveling-wave is reflected and the other penetrates it. Thus, in case of an open end line such as the test line, noise current is reflected in part and forms a standing wave along the test line. And the frequency spectra are not simply reduced along with the frequency and each frequency has both maximum and minimum level. Fig. 14 shows the frequency spectra of measured on Kochang 765 kV test line. As using a gap noise generator installed on the line explicitly shows these extreme levels, a gap noise generator is installed on the test line to obtain the frequency spectra.

Conversion factor for predicting RI from infinite lines is obtained by the geometrical average method on the basis of maximum and minimum values measured on the finite test lines. The geometrical average method is to obtain a frequency characteristic curve [dotted line in Fig. 14] of an infinite line on the basis of maximum and minimum values as shown in the Fig. 14. Television bandwidth, however, needs not such additional correction process as it has higher frequency than radio bandwidth.

**4.4 Longitudinal Profile** Measuring the longitudinal profile of RI generated from line conductor was performed while moving the measuring vehicle from point D to E shown in the Fig. 8. Fig. 15 shows the results of measurement in the span between −110 m and 480 m along the line, with the x coordinate of tower #2 of the test line set as the origin. In the Fig. 15, it is shown that RI is measured largest at −100 m point [midspan of tower #1–#2] and 150 m point [midspan of tower #2–#3] in the span between −100 m and 300 m owing to the

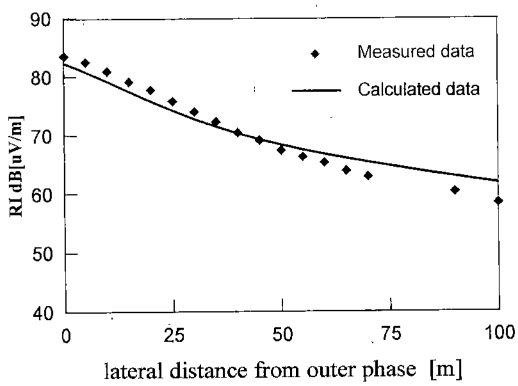



Fig. 12. Lateral profile of RI from test line

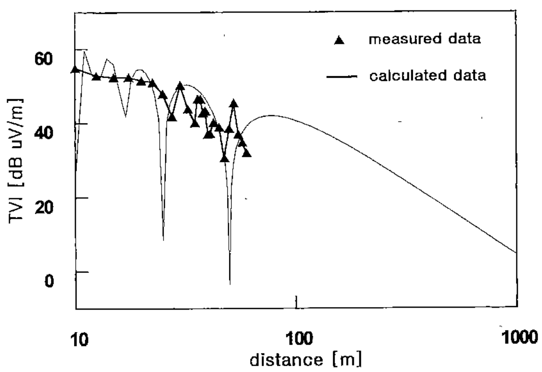



Fig. 13. Lateral profile of TVI from test line

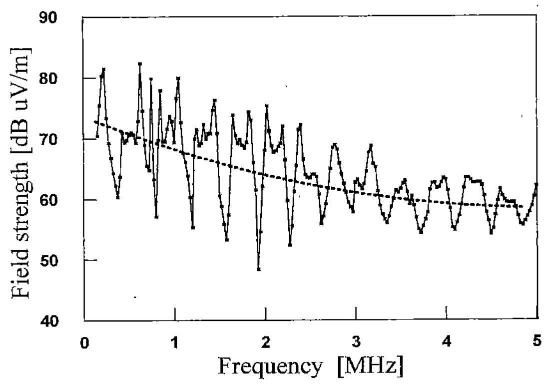



Fig. 14. Frequency spectra of line noise measured by gap noise generator

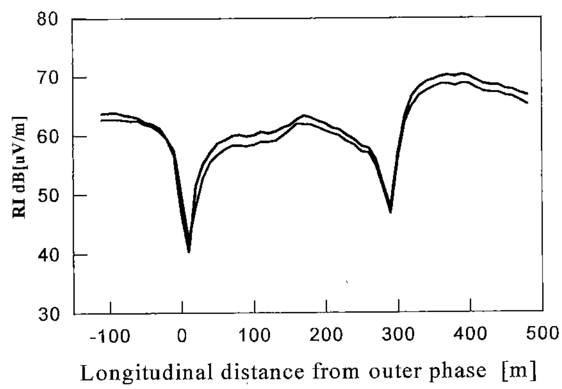
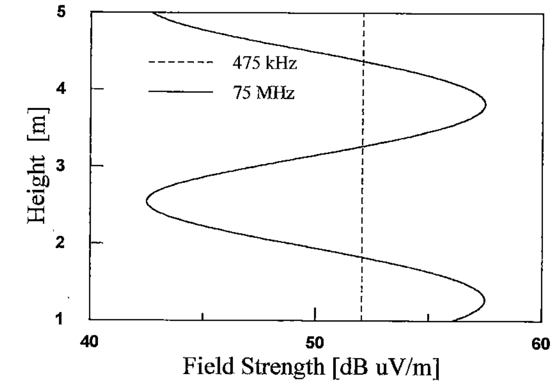
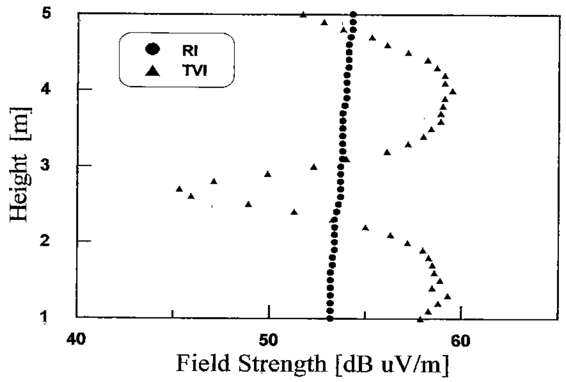



Fig. 15. Longitudinal profile on test line (resulted from 2 measurements)




(a) Calculated value




(b) Measured value

Fig. 16. Noise height pattern on test line

influence of dip of the test line. And it is verified that location of the loop antenna installed between tower #2 and #3 of Kochang 765 kV test line is the mechanical and electrical center of the line.

**4.5 Height Pattern** Noise field strength is varied by height while the receiving antenna is perpendicularly raised from the ground.

This is because there is interference occurring between noise arriving directly to the receiving antenna via propagation through the air and one arriving after reflected on the ground surface. Fig. 16 shows the calculated and measured noise field strength when the antenna is raised from 1 m to 5 m at 20 m far from the test line. In this measurement, it is confirmed that RI is consistent in the radio frequency bandwidth with little affected by the distance but TVI regularly moves between the maximum and minimum as the height is larger.

## 5. Conclusion

Radio and television interference characteristics were surveyed with a gap noise generator installed on Kochang 765 kV test line and the results are as follows.

(1) Sources of RI from transmission line are corona discharge of conductor and gap discharge of adjacent facilities and, in case of TVI, the source is gap discharge of adjacent facilities mainly

(2) RI reduces in exponent proportion to distance but TVI reduces after repeatedly moving, depending on line configuration and measuring frequency, by dozens of or hundreds of meters between minimum and maximum value.

(3) Conversion factor for predicting RI from infinite lines can be easily obtained by using a gap noise generator on finite lines such as a test line

(4) It is verified by the longitudinal profile that location of the existing antenna in Kochang 765 kV test line is the mechanical and electrical center of the line.

(5) Perpendicularly raising the height of antenna scarcely varies RI but moves TVI between the maximum and minimum values regularly.

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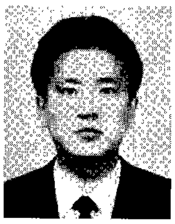
## References

(1) W.E. Pakala and V.L. Chartier: "Radio Noise Measurements on Overhead Power Lines from 2.4 to 800 kV", *IEEE Trans. Power Apparatus Syst.*, Vol.PAS-90, No.3, pp.1155–1165 (1971-5/6)

(2) CIGRE Working Group 36.01: "Interferences Produced by Corona Effect of Electric Systems Description of Phenomena Practical Guide for Calculation", Part 3, Chapter 7, pp.89–97 (1974)

(3) Japan CATV Technique Institute: "The Guide of Obstacle Prediction by a Structure", pp.1–5 (1995-9)

(4) "Analysis of Radio Interferences Wave Propagation in Transmission Lines—A Computation Method for Non Uniform Eines—", CRIEPI 186002 (1986)



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