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An Approach to Estimate a Micropulse Width with Nearfield Spectra Measurement using Slot Antennas

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Abstract

The spectra of the electromagnetic field around the electron LINAC beam was measured with small slot antennas. The shown spectra are described as the products of frequency response of the slot antennas and the LINAC beam spectrum, which depends on the micropulse structure of the beam. The results show that the detected signals were mainly harmonics, since the size of the antennas were smaller than the wavelength of the acceleration microwave. The results of numerical analysis shows that the frequency characteristics of slot antenna depend on the size of antenna plate and internal cavity structure.

1 Introduction

There are several types of non-destructive beam monitors. Some monitors use electrostatic induction by charged particle beam, the other detects magnetic fields induced by beam current, another one uses synchrotron radiation, and so on. The pulsed beam, such as a LINAC beam, generates harmonic electromagnetic fields around it. The frequency of fields is characterized by the pulse interval. We have taken note of this fields, and have studied a non-destructive beam position monitor that detects the fields by slot antennas.

The behavior of slot antenna on a infinite screen of electric conductor is explained as a magnetic current dipole antenna. The slot length is usually a half of wavelength for communication use. For our beam position monitor, however, the conductor plane size is limited to a few times of wavelength of acceleration microwave, and the slot length must be smaller than plane. Nevertheless, in the case of the pulsed and bunched beam, the fields have many higher order harmonics. Therefore, this small slot antenna can detect the harmonics component. Because of the spectrum of the electromagnetic fields around beam depend of the micro-pulse structure, this structure is estimated form the spectrum if the frequency response of the measurement system is known.

In this paper, it is shown the spectra of electromagnetic fields adjacent to an electron LINAC beam detected by various size slot antenna. The frequency response of simplified model of slot antenna is shown by numerical analysis.

2 Spectra Measurement

2.1 Measurement System

Fig.1 shows the structure of the slot antenna. A slot is made on the center of one surface of a copper coated rectangle dielectric plate. The relative permittivity of dielectric is about 4.8. The detected signal is fed to the coaxial cable, that connected to the center of both edge of the slot from backside plane through a SMA receptacle. Three different size slot antennas were used to detect the harmonic fields. The size of dielectric plates are shown in Table 1. The slot width and length are 3mm and 6mm, respectively.

Table 1
Plate Size of Slot Antennas

	width	height	depth
No.1	12mm	24mm	1.6mm
No.2	18mm	36mm	1.6mm
No.3	24mm	48mm	1.6mm

The measurement system is shown in Fig.2. The slot antenna was set adjacent to the beam, and the slot was directed to upstream side. To avoid the scattered electromagnetic wave, the antenna area was surrounded by microwave absorber walls.

The antenna output signal was passed through band pass filter(BPF) and modified by crystal detector HP423B. It converted high frequency signal to the envelope, and we read out the envelope peak with oscilloscope. The each BPF passed the dominant frequency of the acceleration microwave (2855MHz), the 2nd harmonic and up to 8th harmonic(22.84GHz), respectively.

In this measurement we used the 45MeV electron LINAC at Hokkaido University. Its macro pulse width was 10ns and beam current was 40nA at 10 pulse per second.

2.2 Results

Fig.3 shows the spectra of each antenna output. The horizontal axis denotes the frequency, and the vertical axis denotes the peak power of the antenna output signal. It is corrected by total account of the cable and the BPF insertion loss and the sensitivity of the crystal detector based on measured value for each frequency. Therefore this spectra show the product of electromagnetic fields spectrum around the electron beam and frequency characteristics of each slot antennas. When the micro-pulse has gauss function shape with 20ps FWHM, the power spectrum of fields becomes gauss function that characteristics has −3dB down at the 5th harmonic frequency. In our results the power of acceleration fre-

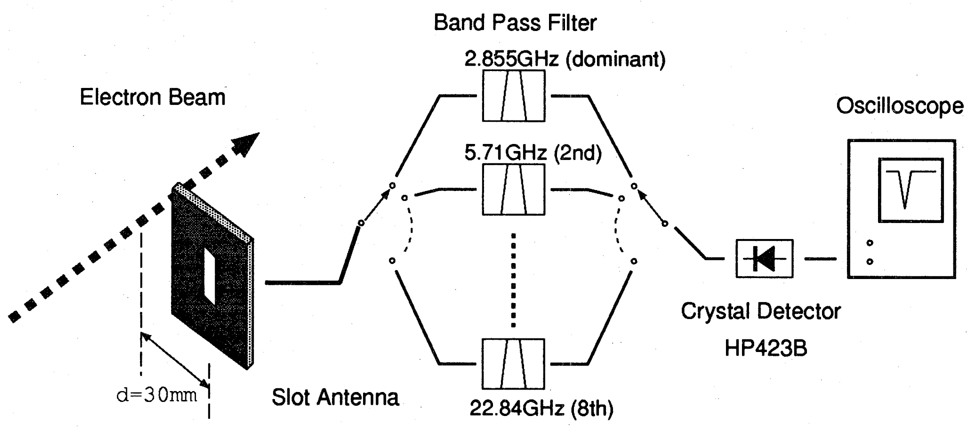

Fig. 2 Measurement System

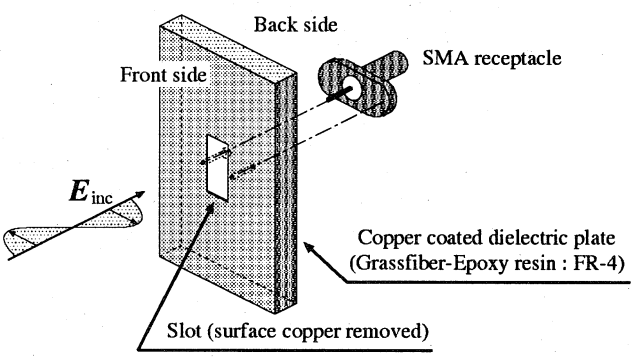

Fig. 1 Structrue of slot antenna

quency are smaller −10 or −20dB than main component harmonics. The reason of this result is that the 6mm slot length is too small for acceleration frequency. Furthermore, since the antenna plate size is larger than the wavelength of many harmonics, it is thought that the effect of surface current distribution and cavity resonance of internal of dielectric plate are involved.

The spectrum of the beam can be calculate from the spectrum in Fig.3 in consideration of the frequency characteristics of slot antennas. However, it is difficult to determine the frequency characteristics of slot antennas experimentally, because of the necessity of near-field response.

The numerical analysis of frequency characteristics of slot antennas are described in the following section.

3 Numerical Analysis

To determine the frequency characteristics of slot antennas, two simplified models shown in Fig.4 were analyzed numerically. The Model I, a simple plate model, is a slot on a perfect conductor plate. The plate and slot size are same as the actual antenna that used in the above experiment, except plate thickness, 2mm in this model. The Model II, a cavity model, is a slot on a perfect conductor rectangle cavity. Its outer size and slot size are same as antenna No.1 except thickness, 5mm in

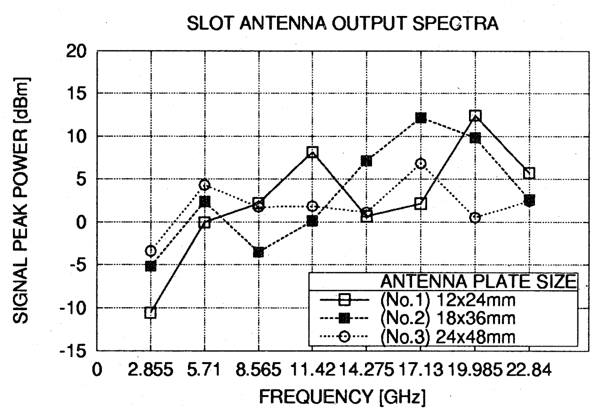

Fig. 3 Spectra of Output of Each Slot Antenna

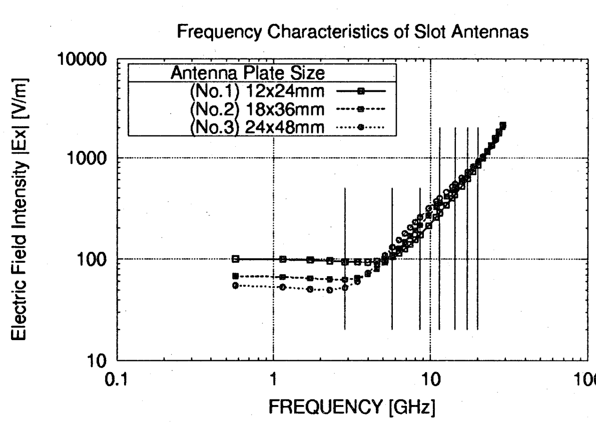

Fig. 5 Frequency characteristics of slot antennas, Model I (simple plate model)

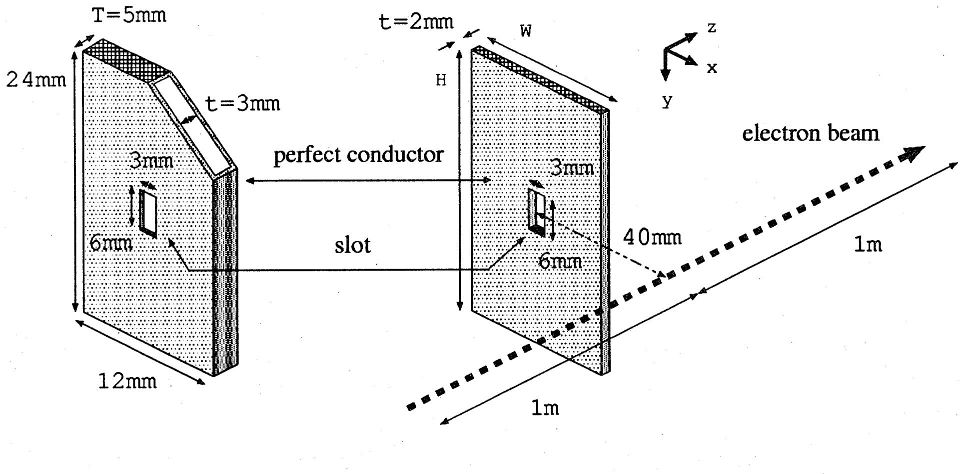

Fig. 4 Numerical Analysis Models

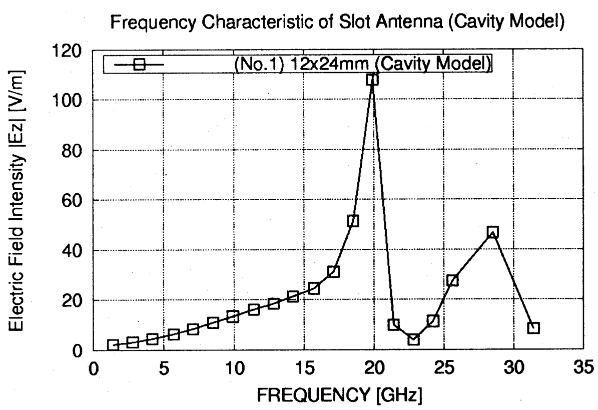

Fig. 6 Frequency characteristics of slot antennas, Model II (cavity model)

this model. The conductor thickness is 1mm and internal width, height and depth are 10mm, 22mm and 3mm, respectively.

For simplification, both models are not considered feeder section and load. Therefore, the output of the antenna is evaluated by the intensity of the electric field directed to across the slot at the center of slot aperture for Model I, directed to depth at the center of cavity for Model II.

The boundary integral equation method (BEM) was used to solve the Helmholtz equation of electric fields in 3-dimensional space and frequency domain.

In Fig.5, the results of Model I show that the output of antenna is growth with frequency if the quarter of wavelength is shorter than the plate width.

In Fig.6, the result of Model II shows that the output of antenna makes a peak near the cutoff frequency of cavity resonant mode 210. It is fc_{210}=20.3GHz for the dimension of this model. Therefore, it is capable of selecting a detection frequency.

The fc_{210} of the slot antenna No.1, No.2 and No.3 used in the measurements in previous section are 8.4GHz, 5.6GHz, 4.2GHz, respectively. The measured spectra of Fig.3 have small peaks near the fc_{210} for each antenna, but the main components of spectrum are higher frequency than fc_{210} of each antenna. It is thought that the frequency characteristics of actual slot antenna is involved both characteristics of Model I and II, because the feed lines from slot to coaxial cable pick up the field directed to across the slot and also directed to depth.

To estimate the micro-pulse width from near-field spectrum, it is necessary to analyze the more precise model include the feed line.

4 Conclusion

The electromagnetic fields spectra around the electron LINAC beam was measured by three difference size small slot antennas. It is shown that these small slot antennas detect harmonics mainly. The frequency characteristics of these antennas depend on outer plate size and inner cavity behavior. More precise model of numerical analysis is needed to estimate the micro-pulse width from measured fields spectra.

References

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