

How Spread Spectrum Clock Generators Accelerate FCC Certification of System Designs

W H I T E P A P E R

Introduction

Controlling electro-magnetic emissions is a key consideration of systems design. In today's advanced electronic products, most of the electromagnetic radiated emission originates from the high-speed digital clock signal. As the clock frequency increases, more Electro-Magnetic Interference (EMI) is generated.

This creates a problem because the Federal Communications Commission (FCC) and other regulatory bodies tightly regulate the maximum amount of EMI that any electronic device may emit. These regulations are designed to make sure that electronic devices will not interfere with each other (e.g., that a person does not lose TV reception when talking on a cell phone).

This paper will explain EMI and its effect on FCC certification. Alternative approaches to mitigating EMI will be mentioned, and the benefits of using Spread Spectrum Clock Generators (SSCG) explained. Finally the paper will describe the Fujitsu SSCG family, which is designed to reduce the overall bill of materials (BOM) cost, shorten the design cycle time, and enable first-pass FCC certification success without compromising system performance.

EMI and System Design Concerns

To understand why EMI is so important to the FCC, it is helpful to understand the causes of electromagnetic radiation.

When electrical current flows in a circuit, an electromagnetic field is created. The strength of this field depends on the frequency and magnitude of the current flow. This field radiates outward from the wires and electronic traces in the equipment. Any radiation that is an unwanted by-product of the electrical circuitry's desired function is called electromagnetic interference or EMI.

The sources of electromagnetic emissions can be intentional transmitters, such as cellular phones. However, digital systems such as PCs, PDAs, printers, scanners, and digital cameras also emit unintentional radiation. In digital systems, high-frequency periodic clock signals are the major causes of EMI radiation because they are periodic with the highest frequency, and because the energy is concentrated not only in the peak but also on discrete frequency harmonics.

Control and timing signals, address and data buses, interconnect flex cables, and connectors also contribute to EMI emissions. This radiation can degrade the performance of either the equipment that generates it or of other nearby (external) equipment.

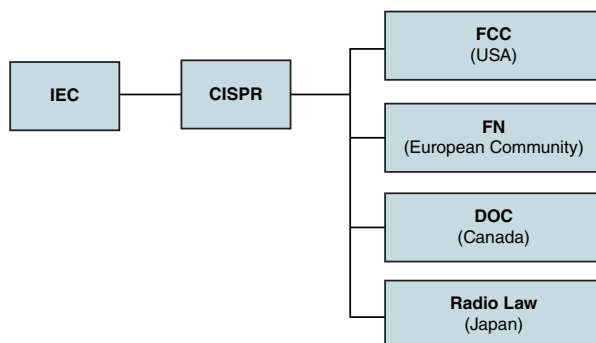


Figure 1 — EMI Standards

Traditionally, shielding and filtering are the most common methods used to control EMI, but they are expensive. As frequency increases, the effects of transmission line and ground impedance amplify the radiation and decrease the wavelength, making shielding and filtering less effective.

Performing critical signal-integrity and EMI simulations during system development is difficult, time-consuming, and error-prone due to reliance on hard-to-predict models and parameter extractions. This situation worsens with every new product generation due to steadily increasing clock speeds and decreasing supply voltages.

FCC Standards

Even though it is challenging, mitigating EMI is essential for FCC and other certifications. The FCC regulates all commercial electronic devices (unintentional radio-frequency radiators) sold in the United States if they:

- employ clocks or oscillators
- operate at a frequency of greater than 9 KHz
- use digital techniques.

This includes almost every product that contains a microprocessor or microcontroller. If an unintentional radiator is not controlled through proper design techniques (e.g., filtering, shielding or spread spectrum modulation), high levels of energy can be radiated or conducted from the equipment, causing unwanted effects on another device. Determining whether one device will impact the functionality of another is not an exact science, and is much too complex to be documented for every combination of products.

However, there are standards to help keep consumers from experiencing problems with their digital equipment. These standard values for electromagnetic waves are being strengthened around the world. The International Special Committee for Radio Interference (CISPR) sets standards for radiated and conducted

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Applications	International Standard	Japan	U.S.A.	Europe
In common	CISPR61000-6-3 Residential, commercial, and light industrial regions IEC61000-6-4 Manufacturing areas			EN50081-1 Residential, commercial, and light industrial regions EN50081-2 Manufacturing areas
Computers and peripherals (ITE), printers, PCs, word processors, displays, etc.	CISPR22	Voluntary Control Council for Information Technology Equipment (VCCI) Electrical Appliances and Materials Safety Law	FCC Part 15 Subpart B	EN55022
Chemical and medical equipment (ISM), radio-frequency equipment	CISPR11	Electrical Appliances and Materials Safety Law	FCC Part 18	EN55011
Ignition equipment for cars, motorboats, etc.	CISPR12	Japanese Automotive Standards Organization (JASO)	FCC Part 15 Subpart B	Directive of End of Life Vehicle (ELV)
TVs, radio, audio, etc.	CISPR13	Electrical Appliances and Materials Safety Law	FCC Part 15 Subpart B	EN55013
Household appliances, portable electric tools	CISPR14	Electrical Appliances and Materials Safety Law		EN55014
Fluorescent lamps, lighting control systems	CISPR15	Electrical Appliances and Materials Safety Law	FCC Part 18	EN55015

Table 1 — List of International Standards

electromagnetic interference in each country as shown in Figure 1 on the previous page. (CISPR is a special committee of the International Electro-technical Commission or IEC.)

As indicated in Table 1, Europe, Japan, Asia, and the U.S. all have different limits. In order to sell an electronic product worldwide, it must satisfy regulatory requirements in each country. Anything that reduces the peak energy will help a product meet the requirements.

To sell an electronic product within the United States, the FCC requires the product have its electromagnetic emissions measured in a specified environment called an EMI range. The device must have electromagnetic emissions in specified frequency bands well below certain specified values.

The FCC and other regulatory bodies are concerned with peak (not average) emissions. The FCC regulates the amount of radiated energy in terms of voltage, distance and frequency. In the United States, the FCC has two classes of radiation levels: Class A and Class B as shown in Table 2. Class A devices are digital devices intended for use in commercial, industrial or business environments and not intended for use by the general public or in the home. Class B digital devices

are intended to be used in the home but could also be used elsewhere. In general, Class B levels are more difficult to meet than Class A.

Table 2 lists the voltage levels allowed under FCC Rules and Regulations (Part 15) for both Class A at 10 meters and Class B at 3 meters.

If the EUT (Equipment Under Test) exceeds these limits, the excess energy must be reduced to within the agency limits as shown in Table 2. Reducing the excess amount of EMI to just under the agency limits is dangerous because differences in manufacturing and environmental changes might cause the energy to increase slightly. Most companies require a safety margin to ensure that the device always complies with

Frequency (MHz)	Class A (10 meters)		Class B (3 meters)	
	uV/m	dB(uV/m)	uV/m	dB(uV/m)
30-88	90	39	100	40.0
88-216	150	43.5	150	43.5
216-960	210	46.5	200	46.0
Above 960	300	49.5	500	54.0

Table 2 — FCC Class A and Class B Limits

agency limits even when manufacturing processes or environmental conditions change. Reducing a particular offending frequency that is over the limit at the fifth harmonic can be difficult. The problem is further complicated when a company imposes a 4dB safety margin.

The products qualified by FCC will have the following logo on them. After such qualification is granted, the product can be sold anywhere in the U.S.



If a company fails to meet the regulatory requirements, it might have to delay shipping or even cancel a product if it can't pass FCC certification in time to capture the market window.

Reasons Electronics Products Fail FCC Testing

The 10 most common reasons products do not pass FCC requirements at first-pass testing are:

1. Ignoring or downplaying FCC requirements during the initial design phase
2. Selecting the fastest components and highest clock rate
3. Using a single or two-layer board instead of a multi-layer PC board
4. Not considering emissions in the clock layout
5. Not using enough bypass capacitors
6. Using unshielded cables
7. Using plastic connectors
8. Not using ferrites in cable design
9. Not incorporating power line filters
10. Not shielding the chassis properly



Figure 2 — EMI Test Facility

Costs of EMI Testing

FCC testing is costly in terms of infrastructure, time and resources.

Measuring EMI requires a large infrastructure and a facility. The EMI test facility can be a small room with several antennas that measure the magnetic waves being emitted (called a closed site) or a large outdoor area taking up many acres (called an open site). A closed site is shown in Figure 2. Such test facilities, equipment and methods must be pre-approved (certified) by the government in order for the results to qualify for legal certification of compliance.

Measuring EMI requires a different approach than other types of general RF tests, and developing comprehensive emission test steps is often time-consuming and expensive. In EMI testing, engineers never quite know what signals might be present. Since each new EUT is different, having the correct tools for characterization of the EMI signals is of key importance. Also, knowing the strengths and weaknesses of the tools being used is vital. Highly trained engineers are needed to perform such testing, increasing costs.

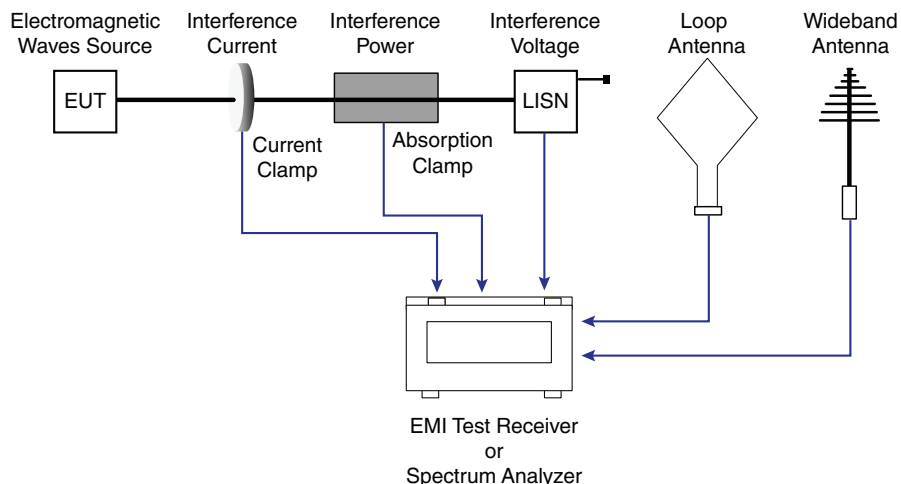


Figure 3 — Example of EMI Measurement Test Set-up

To measure the emission from EUT, the emission must be received via a loop antenna, wideband antenna and a spectrum analyzer or EMI test receiver for measurements as shown in Figure 3 on the previous page.

The paperwork is also daunting. The FCC compliance process requires the following documents and reports:

- Comprehensive Test Plan (details the process and methods employed to test the product)
- Testing for FCC Part 15 Class A or B
- Detailed Test Report with descriptions and standards applied
- Technical File (a collection of technical documents)
- FCC Declaration of Conformity (the official FCC document that states that the product was tested in conformance with the standards, and that it passed)

If regulatory requirements are not met the first time, the engineers need to adapt the EMI shielding techniques. This involves revising the system design and hardware, and repeating all the steps for FCC re-testing.

Figure 4 illustrates such repetitive design changes, a re-qualification that includes PCB layout changes, implementation of filters (which adds to the BOM cost), and the use of an expensive facility again to meet the regulatory requirements.

Ways to Reduce EMI

Taking EMI into account in the beginning, before testing, clearly saves both time and money. Fortunately, there are existing mechanical and electrical solutions to avoid excessive EMI in any system design.

Two common approaches to dealing with EMI are filtering and shielding. Both have definite drawbacks in terms of cost, time and resources.

For example, filtering typically uses about \$.25 worth of resistors, inductors, and capacitors, and often \$.70 worth of common mode chokes and toroids. In many cases, filtering is not enough to allow a system to pass EMI tests, in which case costly shielding may be

required. Shielding can easily add several dollars to the cost of a system.

Spread Spectrum for EMI Suppression

Another method to address signals that emit excessive radiation is clock modulation, also known as spread spectrum. Clock modulation began to appear in computer system designs as early as 1990. Spread spectrum clocking is now popular in portable electronic devices (such as portable navigation and handheld gaming) because of faster clock speeds and the increasing integration of high-resolution LCD displays in smaller and smaller devices. As these devices are designed to be lightweight and inexpensive, passive EMI reduction measures such as capacitors or shielding are not viable options.

The spread spectrum method spreads out the energy using frequency modulation instead of concentrating the reference energy on a single frequency. Unlike filtering and shielding, which suppress EMI after it has been generated, SSCG can suppress EMI at the system clock source itself. Using this method, the system EMI can be reduced as much as 20dB. The reduction is greatest at the higher harmonic frequencies. SSCGs are especially effective for reducing common mode noise, one of the most difficult areas to control.

SSCG clock modulation works by spreading the emissions over a wider frequency band. This band can be broadened, with subsequent reductions in the measured radiation levels, by frequency modulating the MCU or processor clock over a few hundred KHz. Hence it becomes important to understand the factors that determine the optimal profile for a specific system design, accelerating the design process.

Figure 5 on the following page shows that the rate of change in frequency is faster at the minimum and maximum peak frequencies and changes more slowly at the center of the frequency spectrum due to the profile.

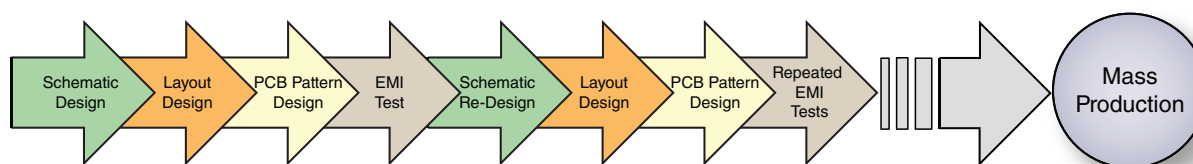


Figure 4 — A Conventional Multi-step System Design Flow for Reducing EMI

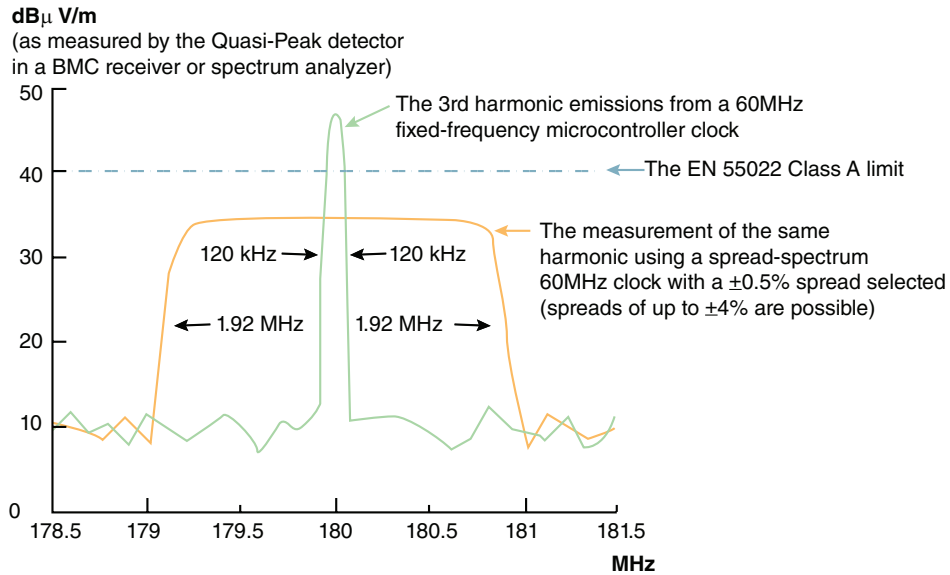


Figure 5 — Rate of Change in Frequency

As indicated in Table 2, the Class B requirement states that the 60MHz clock (as shown in Figure 5) needs to be within 40dBuV/m. The clock modulation rate in Figure 5 is 120KHz. This low frequency modulation rate is important for several reasons. If the modulation rate is below 120KHz, it is possible to generate audible noise in the system. If the modulation rate is too high (in excess of 200KHz), the effect of modulation might be defeated by the loop bandwidth of the filters used in downstream PLLs. Hence, it is important to have optimum modulation techniques and profiles.

In addition to the rate, other important factors to consider when using modulation techniques include:

- Bandwidth requirements
- Modulation type: center-spread and down-spread
- Extent of the harmonic suppression.

Using the spread spectrum technique generally has minimal or no impact on other system performance considerations. Slow and controlled modulation does

not introduce short-term jitter; Fujitsu’s SSCGs typically display the same sub-100ps cycle-to-cycle jitter shown by non-spread-spectrum clocks. The spreading frequency range can be chosen to avoid clock periods shorter than the system minimums.

Overall Benefits of Using SSCG

The systemic nature of SSCG has major advantages over other EMI-reduction techniques. Specifically, the SSCG method can:

- Significantly reduce system-radiated EMI
- Ease FCC certification license approval, speeding up time to market
- Dramatically simplify and reduce the steps for system design (See Figure 6.)
- Increase flexibility in programming optimum modulation profiles
- Reduce infrastructure costs and resources for EMI testing.

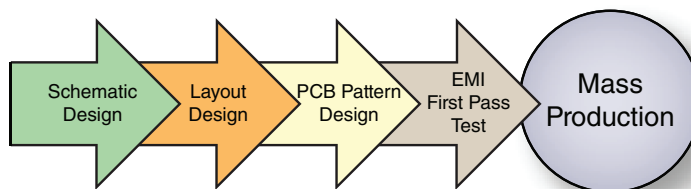


Figure 6 — SCCG Simplified System Design Flow Steps

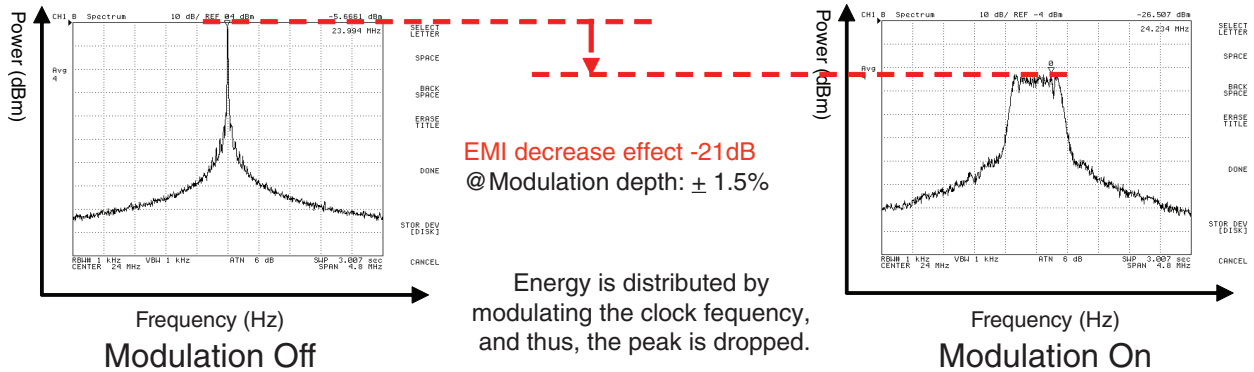


Figure 7 — The Fujitsu SSCG

The Fujitsu SSCG

The Fujitsu SSCG family is designed to shorten the design cycle time, lower the overall BOM cost, and enable first-pass FCC certification success without compromising system performance.

Fujitsu's SSCGs take advantage of digital frequency modulation control technology, which uses multi-cycle modulation. As shown in Figure 7, EMI can be decreased by as much as 21dB and can suppress both the fundamental frequency and the harmonics.

The effects of the EMI decrease in Figure 7 show the ratio of electric power with decibel mark when the modulation is On/Off. This is represented in the following formula:

$$10 \cdot \text{LOG}_{10} (P1/P2)$$

Where P1/P2 is the electric field strength at modulation functions On or Off:

1. EMI decrease effect = 0dB when modulation is off
2. EMI decrease effect = -21.76dB when P1/P2= 1/150

Features and Benefits

Fujitsu's SSCG products offer the following important features:

- Peak EMI reduction on every harmonic, reducing EMI by as much as 20dB
- Cycle-to-cycle jitter less than 100ps, which is very low compared to competitive products
- I/O driving and controlled slew rate abilities
- Digital frequency modulation control technology and multi-cycle modulation
- Programmable spread spectrum modulation percentage and profile for optimizing EMI reduction
- Register programmable, multi-clock (up to 8 clock outputs) and FRAM memory embedded products for design flexibility
- On/off feature, which provides usage on an as-needed basis
- Frequency select feature, which allows users to select among multiple frequencies on the same output pin
- Different output voltage options supported by a single device: 3.3, 3.0, 2.5 and 1.8V
- Variety of industry standards and compact packages for design flexibility

Mobile System Application Example

The following example illustrates the impact of these features on an application. This shows how the Fujitsu SSCG could be used in a mobile phone with no performance degradation.

In this example, as illustrated in Figures 8 and 9, multiple clocks are used for the main CPU, GPS and RF blocks. The main sources of EMI in a cell phone are between the controller, digital signal processor (DSP)

and memory; and on the flex cable that connects to the display.

Figures 10 and 11 show that emission suppression at the main CPU and at the flex cable area is within the FCC regulation limits, respectively.

Adding SSCG to the mobile system design dramatically reduced the EMI and brought the fundamental frequency and its harmonics to within the FCC – Class 15 levels (listed in Table 2 and shown as waveforms in Figures 10 and 11).

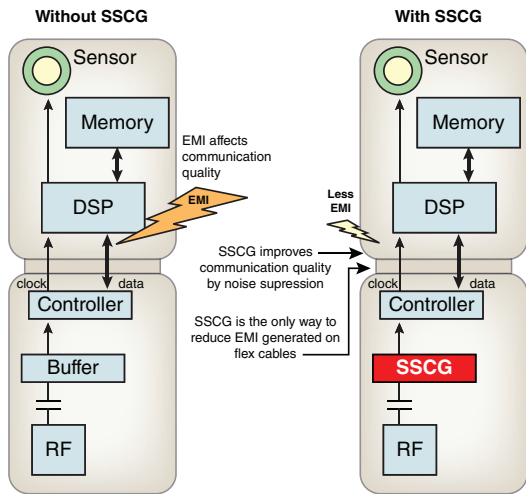


Figure 8 — Mobile Phone SSCG Application Example

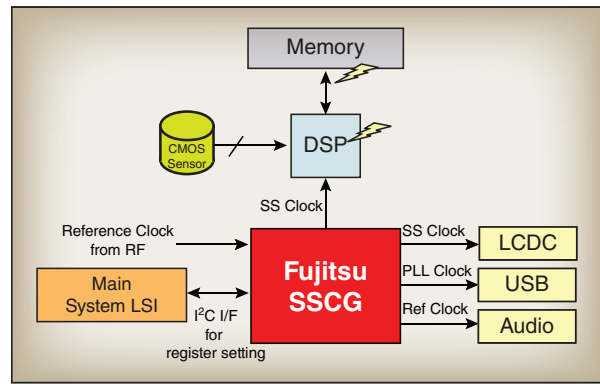


Figure 9 — Block Diagram Showing Multiple Clocks

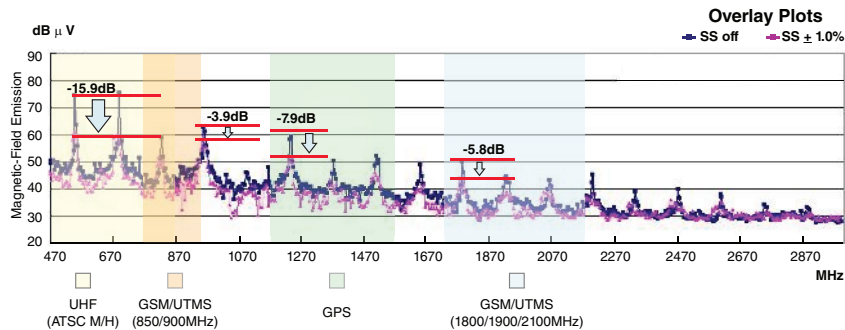


Figure 10 — Emission Suppression at Main CPU Within FCC Regulation Limits

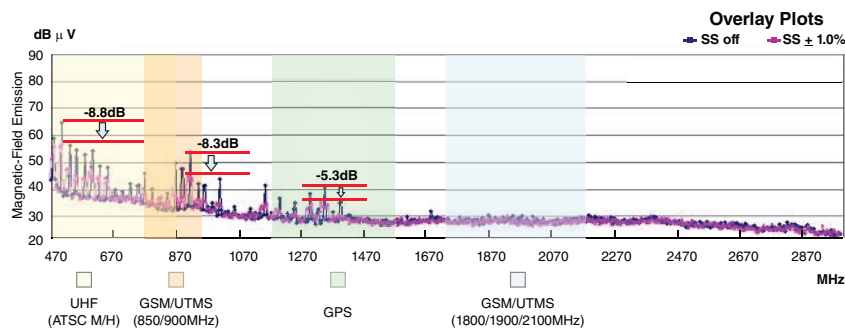


Figure 11 — Emission Suppression at Flex Cable Area Within FCC Regulation Limits

Conclusion

Overall, the systemic nature of the spread spectrum method has major advantages over other EMI-reduction techniques, helping to dramatically reduce EMI throughout the system. The method has enabled system performance to increase without compromising EMI. Using Spread Spectrum Clock Generators reduces packaging, filtering, shielding, and design-cycle costs. Perhaps more importantly, using SSCGs expedites time-to-market for products that otherwise might fail certification testing. Fujitsu's multi-clock output, programmable, low cycle-to-cycle jitter products provide an economical solution to mitigate expensive EMI problems.

For More Information

For more information on Fujitsu Spread Spectrum Clock Generators visit <http://us.fujitsu.com/micro/SSCG> or address e-mail to inquiry@fma.fujitsu.com.

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