

U.S. AND JAPANESE APPROACHES TO SDR AND COGNITIVE RADIO: LEGAL AND CULTURAL FACTORS EXPRESSED IN CERTIFICATION AND TECHNICAL RULES

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ABSTRACT

Software Defined Radio (SDR), Cognitive Radio, and related technologies (Smart Radio) are exciting engineering advances but also important regulatory topics. Both the U.S. and Japan have wrestled with potential interference concerns regarding device conformity in reviewing SDR “certification” rules, and explored the potential of Cognitive Radio to achieve spectrum management goals. Nonetheless, how spectrum management goals are expressed in regulatory policy does vary. Where the U.S. has a growing list of SDR devices available to the U.S. consumer and significant licensed and unlicensed spectrum policy debates incorporating considerations of Cognitive Radio, considerations in Japan have proceeded at a different pace. This paper discusses the cultural and legal issues behind this policy divergence. In particular, the paper suggests that differences in legal authority to regulate radio equipment conformity with technical rules have influenced the pace of policy development on SDR and Cognitive Radio. The paper concludes that despite the differences, U.S. and Japanese policies may simply be proceeding at a different pace, but in the same direction.

1. INTRODUCTION

Software Defined Radio (SDR), Cognitive Radio, and related technologies (Smart Radio) are exciting engineering advances but also important regulatory topics. They hold the promise of helping regulators address the challenge of addressing the exploding demand for spectrum access while at the same time maintaining the integrity of spectrum management process in the information age. As the two largest economies in the world with key wireless development and consumer markets, understanding how the U.S. and Japan approach these topics is crucial. Both jurisdictions have wrestled with such topics as potential interference concerns in reviewing SDR “certification” rules, and explored the potential of Cognitive Radio to achieve spectrum management goals. Nonetheless, how spectrum

management goals are expressed in regulatory policy does vary.

SDR and Cognitive Radio technologies are closely related but in the regulatory context they import different questions. SDR regulatory topics focus on how to maintain the integrity of devices certified as compliant with the relevant spectrum regulations the device is intended to operate under. Cognitive Radio regulatory topics address the potential for a highly dynamic, efficient, and flexible spectrum environment enabled by adaptive radios using advanced “cognitive” processing techniques. Where SDR’s regulatory focus is on preventing devices from causing interference, the Cognitive Radio focus is on improving spectrum management’s allocation, service, and licensing techniques. Cognitive Radio is the hard look at how spectrum is used and regulated and what improvements are possible using adaptive, aware, and learning features. The approach to SDR affects the treatment of Cognitive Radio, and reflects the source of differences in policy approaches in the U.S. and Japan.

In the U.S. SDR is defined in Federal Communications Commission (FCC) rules and the list of SDR devices available to the U.S. consumer continues to grow. In Japan, regulators now permit use of SDR for wireless LANs in the 5 GHz but continue to wrestle with general SDR device conformity issues. In the U.S. Cognitive Radio is an important consideration in significant licensed and unlicensed spectrum policy debates. In Japan Cognitive Radio is a topic of inquiry but one with a research rather than regulatory focus.

This paper discusses the legal and cultural issues behind this U.S. and Japanese policy divergence. In particular, the paper concludes that differences in the legal authority to regulate radio devices’ conformity with technical rules have influenced the pace of policy development on SDR and Cognitive Radio. The U.S. approach to SDR device certification and incorporation of Cognitive Radio to implement flexible spectrum management policies coexists with its authority to regulate the marketing, sale and importation of radio devices. Japanese spectrum management already comparatively conservative, is also

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influenced by this lack of authority. Despite these differences, the paper concludes that U.S. and Japanese policies are moving in the same directions—albeit at different speeds.

2. U.S. APPROACH TO SDR AND COGNITIVE RADIO POLICY

2.1. U.S. SDR Certification Approach

"We neither wish to have our processes inadvertently be a barrier to the development and deployment of these technologies nor wish to permit the widespread deployment of radios easily susceptible of being misused to cause harmful interference to others." [1].

The topic of SDR certification and conformity can be summed up as a problem of who and under what circumstances should a user be able to modify the software running on a radio. In an effort to prevent interference from occurring, governments generally require radio devices to be "checked" with an authority to ensure that they will operate in accordance with the applicable law, particularly the technical rules. The specifics of these legal procedures vary depending on factors including the type of devices involved, but are colloquially referred to as device "certification." Once a radio has been approved as "conforming" with the law it can generally be legally sold to users. Laws generally hold an individual responsible for changes that bring a radio out of compliance. Moreover, for the typical hardware radio, changes that would radically change the frequency, output power, or other important RF features generally require engineering knowledge and hardware parts to make modifications.

For a radio whose RF characteristics are completely controlled by software, changes to the software through "downloads" or other modifications are easier and cheaper than an equivalent change to hardware based radios. Thus from a regulators perspective, radios that could be modified without sophisticated knowledge or even physical changes suggest a need for some kind of special treatment. The difficult question is how to craft this "special" treatment so as to preserve parity between prevention of harmful interference by ensuring devices' conformity with the law, without unnecessarily retarding the flexibility and benefits of using a software-based radio platform. Thus, who can modify a SDR's software and under what circumstances is a focus of the inquiry.

The U.S. FCC policy has sought to balance concerns for flexibility and prevention in crafting SDR policy.¹ After directing its advisory body, the Technological Advisory Council (TAC), to inform on the state of the art and possible

directions for SDR, the FCC adopted a proactive stance on SDR promptly vetting issues and adopting rule changes to accommodate SDR technology in its September 2001 order.[2][3] The changes to the rules defined SDR in the law for the first time and adopted various new "certification" procedures for approval of SDR devices. The FCC adopted procedures for obtaining approval for software changes to a radio, and required devices certified as SDRs to incorporate a means to prevent unauthorized modifications. The FCC created the "class 3 permissive change" which made it easier to make subsequent changes to the software of an approved SDR. Additionally, the new procedure required security measures to prevent third-party modifications to approved software that could potentially result in interference. The modified rules defined SDR as:

*"A radio that includes a transmitter in which the operating parameters of frequency range, modulation type or maximum output power (either radiated or conducted), or the circumstances under which the transmitter operates in accordance with Commission rules, can be altered by making a change in software without making any changes to hardware components that affect the radio frequency emissions."*²

Subsequent to the SDR proceeding in the Cognitive Radio Order, the FCC further modified its rules for SDR requiring that any SDR that could reasonably be viewed as open to modification by someone other than the manufacturer must certify the device as an SDR and have adequate security protections in place to prevent unauthorized modifications to the SDR's approved software.[1]

In both of its actions on SDR certification issues, the FCC demonstrated its commitment to balancing restrictions to preserve the integrity of the SDR approval process without dictating specific implementations. While providing developers flexibility to craft their own solutions, the FCC requires at certification a high-level operational description of the SDR's software that controls the RF characteristics, and as well as the software security measures. In this way

¹Spectrum management in the U.S. is shared by the Federal Communications Commission and the NTIA. Except for use by the federal government the FCC oversees spectrum use by the general public and is the focus in this paper. While U.S. federal government entities have had a long history with SDR and are actively pursuing the benefits of Cognitive Radio, the highly controlled nature of federal spectrum use does not import the same comparisons as use by the general public. This bifurcation of authority presents a variety of interesting policy considerations for SDR and Cognitive Radio but is beyond the scope of this paper.

² See 47 C.F.R. § 2.1.

the FCC policy can ensure new innovations are not stymied at the design and production phase, while still ensuring at the certification phase that necessary preventative measures are in place for any specific device.

2.2 Regulatory Authority over Devices and The Source of The Flexible U.S. Approach

The FCC policy of balancing flexibility and protections is central to its approach to regulating new technologies. This policy heavily depends on the legal authority to ensure that radio devices comply with rules preventing interference before they are marketed, sold, or imported.³ When violations occur the FCC has authority to impose severe penalties.⁴ However, this was not the case in the late 1960's when the U.S. Congress took up the serious problem of how to combat the increasingly burdensome and dangerous problem of harmful interference emitting from malfunctioning or manipulated devices.[4] Congress added Section 302 to the Communications Act in 1968 addressing such interference concerns by strengthening the FCC's power to impose limits on the manufacture of radio devices.

The FCC has commented recently that Congress expanded its authority in the way it did in order to preserve the flexible unlicensed regime and address a need to regulate unlicensed Part 15 devices under its existing regime without having to resort to more formal licensing processes to control the interference potential of such devices.[5] It has described this “pre-check” technique in Part 15 “unlicensed” device approvals as a legal substitute for a formal “license” as required by the Communications act. Thus this “pre-check” authorization process together with the technical rules prohibit the use of equipment or apparatus which may cause interference, and give the U.S. regulator significant opportunity to be flexible in defining its spectrum policy.⁵

³ 47 U.S.C. 302a(b) (codifying section 302 of the Communications Act of 1934, as amended)(“No person shall manufacture, import, sell, offer for sale, or ship devices or home electronic equipment and systems, or use devices, which fail to comply with regulations promulgated pursuant to this section.”); 47 C.F.R. §§ 2.1201, 2.801 et seq.

⁴ For example, the FCC can assess a “forfeiture” of \$11,000 for each violation, or each day of a continuing violation, up to \$87,500 for any single continuing violation, and is specifically authorized to assess a baseline forfeiture amount of \$7,000 for each violation involving the marketing of unauthorized equipment. 47 U.S.C. § 503(b)(2)(D); 47 C.F.R. § 1.80(b)(4).

⁵ Readers interested in this subject may find the deliberations on the need for expanding the FCC's regulatory authority to address harmful interference from non-complaint devices in the field discussed in the Senate Report at page 2486-89

2.3 U.S. Approach to Cognitive Radio and Relationship to SDR Certification

Turning from the benefits of SDR as a platform to the potential benefits of “Cognitive Radios,” the FCC considered how radios capable of adapting spectrum use to the real-time conditions of the operating environment could help achieve more flexible, efficient, and comprehensive use of available spectrum while reducing the risk of harmful interference. With the recommendations of the Spectrum Policy Task Force and input received at its workshop on the topic, the FCC began a rule-making seeking comment on various exciting proposals for the application of Cognitive Radio capabilities.[1][6] In its Notice of Proposed Rule Making the FCC sought comments on: The capabilities of cognitive radios; Permitting higher power by unlicensed devices in rural or other areas of limited spectrum use; Enabling secondary markets, including interruptible spectrum leasing; Dynamically coordinated spectrum sharing; and SDR and cognitive radio equipment authorization rule changes. Cognitive Radio also emerged as a topic in important spectrum proceedings on Rural Wireless Policy, Secondary Markets, Unlicensed Use in Television Bands, and others.[7]-[9] In 2005 the FCC adopted its first “Report & Order” on Cognitive Radio and expressed its intent to continue to explore new and evolving applications of Cognitive Radio.[1]

The FCC made it clear that it viewed Cognitive Radio as important in both “exclusive use” as well as “unlicensed” policy making contexts. Because FCC technical rules for most licensed services already afford licensees significant technical flexibility, the rules typically accommodate new technical approaches such as Cognitive Radio, without significant revisions. Nevertheless the FCC has sought out new ways to exploit Cognitive Radios potential. For example, the technical considerations of real-time spectrum leasing scenarios such as “interruptible” spectrum markets were discussed as early as the Cognitive Radio proceeding itself, and were important in crafting the secondary markets “private commons” leasing technique and other new approaches.[1][7][8][11][12] Such new techniques are backed by enforcement authority against licensees, should the need arise, giving the spectrum policy planner a degree of comfort.

The FCC has also firmly embraced Cognitive Radio in the “unlicensed” or commons-based spectrum regulatory environment. Together with its robust device approval regime, “unlicensed” technical rules can take account of the highly adaptive real-time cognitive capabilities available today, to craft new approaches that would otherwise be impossible. As discussed above in place of a licensee

holding a license, the license-exempt “unlicensed” regime relies heavily on the careful crafting of technical rules and the certification a device's compliance with those limits. With the confidence that devices will comply with whatever technical rules are adopted before they enter the stream of commerce, rules can be crafted to use Cognitive Radio to bring greater value to the public while preventing harmful interference. The proposals for unlicensed use in TV-bands and others demonstrate the FCC's commitment to taking the hard look at the benefits of Cognitive Radio and how they can expand the scope of possibilities in the regulatory context.[7]-[13]

Thus the FCC approach to Cognitive Radio is one of actively seeking out opportunities to use Cognitive Radio to realize new ways for spectrum markets to work, users to cooperatively share, and achieve other regulatory goals. The FCC approach treats Cognitive Radio not simply as an engineering achievement, but as a regulatory tool for accomplishing spectrum management goals.

3. JAPANESE APPROACH TO SDR AND COGNITIVE RADIO POLICY

"The Ministry of Communications, referencing the submitted comments in this proceeding, will proceed by monitoring the direction of R&D for SDR and international activity at the ITU and elsewhere."[14] (trans. Miller)

SDR has a rich history in Japan as an important academic research topic and a subject of inquiry with the Ministry of Communications (MIC).[15]-[19] Nevertheless, except for frequency selection control software for a class of wireless LAN's in the 5GHz, SDR is not permitted in Japan. Likewise, key drivers of regulatory interest of SDR and Cognitive Radio in the U.S., e.g. secondary markets and unlicensed authorizations, are absent from major discussions in Japan. As is the case in U.S. the benefits of SDR and Cognitive Radio are an important tool for addressing the exploding demand for spectrum services and access in the highly-congested Japanese spectrum market place. Cognitive Radio has assumed a place of importance in the “ubiquitous” policy discussions that will likely propel it forward.

Activity on SDR in Japan began in 1996 with a study by the Association of Radio Industries and Businesses (ARIB) followed by the formation of the Institute of Electronics, Information and Communications Engineers (IEICE) Software Radio Technical Group SR-TG in December 1998 —today a permanent committee since 2005. As interest in SDR grew, Telecom Engineering Center (TELEC) in 2000 under commission by MIC formed a study group of experts

and provided important insights on SDR testing and conformity issues. Following the 2001 policy activity in the United States, the FCC, MIC and the SDR Forum held a workshop on SDR regulatory issues. In December 2003, MIC sought comments on security, certification and other aspects of SDR and related technologies, garnering significant interest.[22] In 2005, MIC released a summary of the comments and proposed a “Cognitive Radio” use of SDR with 5 GHz DFS wireless LANs, later adopting the proposed changes to allow the first SDR use in Japan in April of 2005. However, MIC's stated intent to follow the state of development of the technology and work at the ITU, and the overall pace of the inquiries reveal a cautious stance on SDR.

The more cautious Japanese stance on SDR is easily understood in light of how critically equipment authorizations must be considered. While the specific rules and procedures for equipment authorization in Japan and the U.S. may differ on various points, the crucial difference is not in how radio emissions are measured, the kinds of fillings required, or system for approved testing bodies.[22] The important difference lies in what authority the U.S. and Japan have to enforce their rules.

Where revisions to the U.S. Communications Act provided the FCC authority to combat interference potential through equipment authorizations before they enter the stream of commerce, MIC lacks this regulatory authority. In its place MIC primarily relies on costly and burdensome field enforcement employing, among other tools, a highly-advanced spectrum monitoring network (DEURAS) to track illegal “unlicensed” emissions in real-time. It also expends considerable funds on outreach which is why you may see posters with “stop the illegal spectrum emissions” around the Tokyo subway system. Whether to give MIC regulatory authority over marketing, sale and importation of radio devices, in Japanese “hanbai kisei,” has been a constantly recurring topic, but it has never reached fruition. Lacking this authority, naturally Japanese regulators may feel more concern for devices that are produced under broad definitions, and prefer to allow new approaches only under clearly defined standards. Indeed, MIC's pace with SDR demonstrates it is paying very close attention to the role of security and device integrity and monitoring the state of development as it matures.[14]

3.1. Japanese Approach to Cognitive Radio and Technical Rules

As discussed above enforcement concerns with devices' conformity with technical rules naturally influence a regulator's comfort level for flexibility in the “licensing” of

and technical standards for spectrum use as well. This discomfort about enforcement together with the Japanese general conservative cultural bias may further explain regulators' cautious stance on SDR and reluctance to explore new licensing and unlicensed regulatory opportunities that leverage the capabilities of Cognitive Radio.

U.S. spectrum policy today relies heavily on markets for allocating spectrum licenses, defining appropriate entrants, and license transfers (from failed players or merging entities). In contrast the Japanese approach to allocations and licensing is to follow international activity and vet with key players in various research committees and advisor boards what new technologies should be employed in what bands. After having "refined" the discussion, it will conduct a rulemaking. Some Japanese regulators view with significant discomfort (if not hostility) the "U.S. approach" described by volatile market changes marked by frequent entry and exit of players (sometimes through gasp, bankruptcy), technologies, and service offerings. Stability valued over flexibility is not only a general stereotype of Japanese culture but a generalization apropos to spectrum policy.

The administrative law regarding public comment filings and petitions is the source of another significant difference in approach especially important for Cognitive Radio. The Japanese Administrative Procedures Act (JP-APA) was revised last year to include provisions for public comment rulemakings. Public comment procedures existed before as a cabinet level order but were not on par with the U.S. APA. After the revision the U.S. and Japanese APA are largely identical save two points. The first is the lack of an opportunity to petition for creation of new rules or modification or rescission of existing rules found in the U.S. APA.⁶ In the U.S. anyone can file a petition for rulemaking, and much innovative policy originates there. No such formal procedure exists under Japanese law.

In addition, when comments are filed in the U.S. under FCC procedural law, parties have an opportunity to read all submitted comments and file a reply in response. The opportunity to respond directly to arguments made in submitted comments affords the parties an opportunity to develop a full debate that the regulator can use as a guide in making decisions. The lack of any of these features can dilute the overall debate or prevent issues from coming forward to begin with. However, from the Japanese perspective, a more focused inquiry can avoid wasteful legal gamesmanship and solicit valuable insights from the truly interested parties. Opinions about rulemaking approaches

⁶See 5 U.S.C. § 553(e) ("Each agency shall give an interested person the right to petition for the issuance, amendment, or repeal of a rule.").

vary within Japan, and even the U.S. has recognized some value in the Japanese rulemaking techniques in the past with the adoption of the administrative law for negotiated rule-making. The long history of scholarly debate continues to weigh the pros and cons of each approach.[23]-[25] While, the U.S. APA does not require the above "reply" comment process, it is a valued part of the procedural rules of the FCC and other regulatory bodies. Whether MIC or other Japanese Ministries could evolve a reply comment process independently imports legal questions itself, but irregardless a requirement in the JP-APA could ensure the benefits of the approach with uniform practice and adoption.

While maverick firms are emerging (even those who take unprecedented action such as filing administrative lawsuits against the ministry), a strong consensus requesting Cognitive Radio and SDR rule changes has not been observed in the traditional policy setting by major players. Without a strong consensus it's no doubt been awkward for the regulator to risk significant political capital testing the waters.

Several significant factors indicate that interest in Cognitive Radio and SDR is beginning to pique. The first is of course the regulatory first step of permitting wireless LANs in the 5 GHz to use software in implementing interference avoidance and frequency selection schemes.[14] Also Cognitive Radio has been raised in the context of recent MIC requests for comments regarding the digital-analog TV transition.[26]-[28] In October 2005 MIC also issued a request for proposals regarding improved spectrum efficiency research funded by spectrum usage fees.[26] Among the many research topics available for proposals, MIC included substantial funding for a 3-month 1.4 Billion Yen (@\$1.4 mil.) project for R&D on Cognitive Radio technology directed at shared mobile technology. This clear commitment to the potential of Cognitive Radio is very encouraging, and at the same time quite predictable under the Japanese approach. It is common for Japanese regulators to fund research until a technology matures sufficiently to go forward in the regulatory context.

Outside of the factors suggesting a change in regulatory posture, there is significant demand brewing in the public for low-cost ubiquitous wireless access and new players are moving to meet the demand. Japan's wired broadband network market is a global leader. That market developed largely as a result of very aggressive new entrants (one in particular, Softbank) competing on price. Likewise new entrants in the wireless space employing disruptive technologies are poised to compete against a handful of old-school competitors. When the stars align the seasoned service and handset manufacturers will not be left behind. Particularly as unlicensed technology permeates consumer

electronics in the home, highly agile flexible radios will play an important role in satisfying such a market's demand. It is clear products are being developed and could enter the market soon. KDDI demonstrated a "cognitive radio" system at the Wireless Japan 2007 trade show sporting a virtual MAC layer that selects between various 3G (CDMA 2000 1x EV-DO) and WiFi (802.11a/b/g) using sending hardware to achieve seamless "white-space" channel selection.⁷ However, Japanese law may need to change to take SDR and Cognitive Radio fully out of the lab and in the hands of consumers.

4. CONCLUSIONS AND FUTURE DIRECTIONS

Regulators in the U.S. and Japan have asked many of the same questions but adopted different approaches in response. The answer to why Japan and U.S. approaches do differ is part law and part culture. Differences in the underlying legal authority of the regulators affect their stance on certification and technical rule flexibility in licensed context and advanced techniques in the unlicensed context. Even with changes to Japanese law on regulatory authority, U.S. and Japanese regulators will still have different comfort levels regarding technical and regulatory "flexibility" that ultimately will effect the pace and direction of new technology adoption. Nevertheless, a higher level of comfort regarding enforcement would benefit Japanese regulators and encourage more flexibility in spectrum allocation and licensing policy to harness new engineering techniques and novel spectrum management techniques.

Without serious discussion between interested ministries about the potential merits and risks of taking action on SDR, it is unlikely any change to the status quo would be possible. The Japan public would benefit from avoiding the problematic spectrum enforcement concerns that brought such debates to the U.S. Congress in the 1960's. Moreover, policy changes could usher in the potential benefits broader SDR and Cognitive Radio adoption can offer.

⁷ The testing prototype demonstrated many exciting features but as described by the KDDI official is a research endeavor and commercial deployments remain a topic for the future.

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