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IDENTIFICATION AND MAPPING OF CELLULAR TELEPHONES TO DEFEAT RADIO-CONTROLLED IEDS

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THESIS

IDENTIFICATION AND MAPPING OF CELLULAR TELEPHONES TO DEFEAT RADIO-CONTROLLED IEDS

by

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June 2018

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The purpose of this thesis is to develop a means of identifying and mapping radio-controlled improvised explosive devices (RCIEDs) that use cellular telephones as a means of activation. By understanding the regulating bodies that allocate and control the frequency bands within the electromagnetic spectrum, this thesis tests the validity of deriving required inputs for a mathematical algorithm to compute the range to an emitting cellular device. Computationally deriving the range and coupling it with the direction-finding capabilities of spectrum analyzers will enable the development of a handheld device in the future to map the location of cellular telephones in the operating area around a ground unit. Possessing the ability to map the location of emitting devices will enable ground units to not only safely bypass an RCIED but defeat it before detonation.

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IDENTIFICATION AND MAPPING OF CELLULAR TELEPHONES TO DEFEAT RADIO-CONTROLLED IEDS

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from the

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ABSTRACT

The purpose of this thesis is to develop a means of identifying and mapping radio-controlled improvised explosive devices (RCIEDs) that use cellular telephones as a means of activation. By understanding the regulating bodies that allocate and control the frequency bands within the electromagnetic spectrum, this thesis tests the validity of deriving required inputs for a mathematical algorithm to compute the range to an emitting cellular device. Computationally deriving the range and coupling it with the direction-finding capabilities of spectrum analyzers will enable the development of a handheld device in the future to map the location of cellular telephones in the operating area around a ground unit. Possessing the ability to map the location of emitting devices will enable ground units to not only safely bypass an RCIED but defeat it before detonation.

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LIST OF ACRONYMS AND ABBREVIATIONS

3G	third generation
4G	fourth generation
CMC	Commandant of the Marine Corps
CPOF	command post of the future
EMS	electromagnetic spectrum
FBCB2	force XXI battle command brigade and below
FCC	Federal Communications Commission
FCC ID	Federal Communications Commission identifications number
GHz	gigahertz
GPS	global positioning satellite
HF	high frequency
IED	improvised explosive device
IEEE	Institute of Electrical and Electronic Engineers
IR	infrared
ITU	International Telecommunications Union
JCREW	the electronic warfare, joint crew
JIEDDO	joint IED defeat organization
MHz	megahertz
MRAP	mine-resistant ambush protected
MRI	magnetic resonance imaging
mW	milliwatt
RCIED	radio controlled improvised explosive device
VHF	very high frequency

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I. INTRODUCTION

A. BACKGROUND

Communication is a key component of the active command and control of a military unit. Many leaders and operators, however, do not have the time to consider how the basic physics of their communication systems depend upon the electromagnetic spectrum (EMS); nor do they consider the signatures that their communication devices produce. The current Marine Corps Operating Concept emphasizes the importance of managing these signatures to the future of combat. It states,

> We must acquire the offensive capabilities to raise and detect enemy signatures across the spectrum, quickly and accurately assign meaning to what we observe, and rapidly take action to exploit any opportunity. Defensively, our units will need to adapt how they fight, emphasizing emissions control and other means of signature management to increase their survivability. (Commandant of the Marine Corps [CMC], 2016, p. 6)

Advancing ways to detect and manage signatures within the EMS will enhance both offensive and defensive operations into the future.

As the world continues to rely upon and expand its use of advanced technologies, being able to access the EMS will be vital to both daily life and military operations. Things such as radar and infrared light use the EMS to produce images and give individuals situational awareness. Moreover, wireless digital communication depends upon the EMS to operate. As wireless device use continues to grow, so too does the congestion within the EMS. Therein lies a problem: the EMS is being used so prevalently that operators cannot know when adversaries are using it against them.

If one possessed the ability to sense the flow of EMS traffic, he or she could analyze patterns and extrapolate data from that information. A person or unit would be able to make informed decisions on how to best operate in an area where adversaries are using the EMS combatively. This thesis investigates a cost-effective means of coupling off-the-shelf technologies with a computational algorithm to provide warfighters the ability to gain situational awareness about devices transmitting in their local area.

B. PROBLEM STATEMENT

People do not normally consider how their communication devices utilize the EMS. They touch a button on a cell phone, or type a password into a computer, and are instantly connected to other users. When devices communicate, they produce signatures that can be triangulated and tracked. Warfighters currently do not possess the ability to sense and become aware of the EMS around them, or more specifically, how their adversaries are using it against them.

Having become aware of the gap in their current operating procedures, signature management is at the forefront of many current military discussions. How will the military be able to effectively operate in an environment in which adversaries can sense, track, and degrade communications? When addressing the issue of signature management, the Marine Corps Operating Concept keeps at the forefront of the discussion the idea that “to be detected is to be targeted is to be killed” (CMC, 2016, p. 6). Given the state of current tactical operations, this idea does not bode well.

In the past 17 years of counterinsurgency operations, improvised explosive devices (IEDs) have become a prevalent weapon on the battlefield. The military has developed measures to disable and prevent the IEDs from detonating, but these rely upon intense training of visual recognition to identify the locations of IEDs. Radio-controlled improvised explosive devices (RCIEDs) are a more advanced form of IEDs used by our adversaries and are harder to identify. RCIEDs generate a signature within the EMS when in place or while activated that can be exploited. The Marine Corps Operating Concept emphasizes the understanding of signatures, stating, “a key factor will be our ability to control and minimize our signature and raise and identify adversary signatures” (CMC, 2016, p. 17); however, the means of identifying those signatures has not been given to the mobile ground units who conduct operations.

C. PURPOSE

This thesis conducts an analytical study of signature identification and designs a mathematical algorithm to generate an operationally effective means of sensing and mapping cellular emitters in the EMS. Moreover, it researches the efficacy of coupling off-the-shelf electromagnetic sensing equipment with a computer-based algorithm in enabling units to identify and triangulate cellular devices in their operational area. Understanding the regulatory bodies that control and manage the use of the EMS, this thesis will use open-source information to accurately generate the mathematical algorithm from computational inputs. Combining the open-source information with the Friis mathematical equation on wave propagation and off-the-shelf direction-finding equipment will enable the reverse triangulation of emitting cellular telephones in an area. Plotting the known location of emitting cellular telephones on a user interface that is recognizable and easy to use will empower a squad to gain situational awareness of EMS, enhancing both force protection and lethality.

In line with the concept of combined arms and information warfare laid out in the Marine Corps Operating Concept, this thesis will develop an algorithm to detect, and to enable the attack of, the adversaries' use of the EMS (CMC, 2016). Warfighters will be able to apply this research to sense their surroundings for emitting cellular telephones. Knowing the location of cellular signals has many beneficial uses, such as the ability to track communication patterns, track spotters for patrols, and identify the location of cellular RCIEDs.

D. SCOPE

This thesis develops a mathematical algorithm and designs a procedure for units conducting ground operations to identify and map cellular telephones. It is beyond the scope of this thesis to build a working prototype of the device discussed.

E. RESEARCH QUESTIONS

The following questions guide the research in this thesis as it aims to support the sensing and mapping of transmitting devices in an operational area:

1. What information does a warfighter need to know about an emitting cellular device in order to locate and triangulate its position?

2. What spectrum analyzer specifications are required to support the development of a device that can locate and triangulate cellular telephones?

3. Can a mathematical algorithm be designed to process information from a spectrum analyzer that enables the mapping of transmitting devices?

4. How can a mathematical algorithm be applied to a system in order to enable the mapping of cellular telephones in a local area?

F. THESIS ORGANIZATION

Chapter I introduces the reader to the central idea of this thesis. It states the problem and discusses how to fulfill the capabilities laid out in Marine Corps guidance. Finally, Chapter I presents the research questions and the structure the thesis takes to answer them.

Chapter II investigates the need for the capability to locate and triangulate emitting devices. The literature review discusses the founding principles of the EMS, providing the reader with big-picture concepts, such as what the EMS is and how it is regulated. The literature review also explains the application of a mathematical algorithm to the problem as the method for generating an accurate solution.

Chapter III discusses how understanding the regulatory allocations of the EMS in the United States and other large markets can lead to accurately generating key variable inputs for a mathematical algorithm. The chapter presents an example of the methodology for deriving the variable power transmitted (P_r) for cellular telephones. It then lays out the mathematical algorithm flow of information and processing in order to generate a situational awareness map for the warfighter. This chapter concludes with a discussion on how the information should be processed and plotted into mapping software for the warfighter to see.

Chapter IV discusses the results of the research as well as further refinement techniques discovered throughout the research process. This chapter will explain the analysis of the derived data. The chapter then concludes with a display of the mathematical algorithm that this thesis generated.

Chapter V summarizes the content of the thesis and makes recommendations for testing and refinement to further develop this methodology of mapping cellular devices.

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II. LITERATURE REVIEW

A. THE IED THREAT

In a hearing before the Oversight and Investigations Subcommittee of the Committee on Armed Services for the House of Representatives in 2008, Victor F. Snyder, a representative from Arkansas, stated, “The IED remains the number one cause of casualties to the coalition and the forces in Iraq. More than half of the U.S. deaths due to enemy action have been the results of IEDs” (Defeating the IED, 2008, p. 1). Though the IED is not a new threat, the manner in which adversaries employ it against our forces has developed over years of combat.

IEDs can be triggered in various ways. Graham (2010) defines victim-operated IEDs as those for which the victim of the device commits an action that triggers the emplaced device. These actions, Graham explains, could be as simple as tripping a wire, opening a door, or stepping on a pressure plate. Other manners for activation of IED include command wire detonation and use of pre-timed devices. Graham describes radio-controlled IEDs (RCIEDs) as systems that involve the use of an RF device to initiate detonation. RCIEDs, Graham notes, have many advantages because they do not require a physical link to the device commander, and the range between the commander and the device can be very long.

Cellular telephones have been employed as detonators due to their ability to extend the range between the device and the commander who detonates the device. With cellular telephones, the distance between the tower used for activation and the device could be a few kilometers.

B. CURRENT IED DEFEAT TECHNIQUES

Over the years, many programs have been developed to defeat the IED. In 2006, “the Deputy Secretary of Defense created the Joint IED Defeat Organization (JIEDDO) which was responsible for leading, advocating, and coordinating all DoD efforts to defeat IEDs” (Vane & Quantock, 2011, p. 58). JIEDDO is responsible for many of the devices procured by the military to defeat the IED or to diminish the blast’s effects. For instance, JIEDDO was integral to the rapid procurement of the Mine-resistant Ambush Protected (MRAP) vehicle. In 2005, the Marine Corps initiated an urgent need statement for armored tactical vehicles to increase crew protection and mobility. In September 2007, the MRAP was designated as a major defense acquisitions program. Total procurement funding for the MRAP was about 22.7 billion dollars (Government Accountability Office, 2009). The MRAP has saved the lives of countless military members, but the MRAP was designed to protect the warfighter from the blast effects of an IED after detonation. It was not designed to defeat the IED by disabling its detonation.

While the development of the MRAP focused on protection from IED blasts, radio frequency jamming was a technique employed to prevent, and therefore defeat, the RCIED attack. Northrup Grumman designed the Electronic Warfare, Joint Crew (JCREW) system as a common open-architecture RF jammer for infantry, land vehicles, and fixed sites, and is a program of record designed to disable RCIEDs around a patrol (Drubin, 2015). The JCREW system jams a wide range of frequencies in which RCIEDs operate. Jamming the spectrum prevents activation of the emplaced device trigger while it remains within the protected area of the JCREW jammer.

The JCREW system is just one example of many jamming devices developed over the years to combat RCIEDs. The Thor III and Duke systems were designed to operate much like the JCREW system, but all of these systems had one major flaw: jamming the spectrum to prevent IED detonation did not defeat the IED. Preventing detonation allows forces to pass through an area unscathed, but they would not be aware of an emplaced IED as they bypassed. Once the patrol or jamming device left the area, the IED would reactivate for use at a later time. Fitting a patrol with a device that located a RCIED emplaced around them would allow them to not only safely bypass the IED but also to defeat it.

C. ELECTROMAGNETIC SPECTRUM

Electronic communications are the result of waves in the EMS. The EMS can be visualized by its wavelengths, as seen in Figure 1. The American Heritage Dictionary defines the EMS as being divided into seven major segments. From the lowest frequencies (with the longest wavelengths) to the highest frequencies (with the shortest wavelengths), these segments are radio waves, microwaves, infrared light, visible light, ultraviolet light, x-rays, and gamma rays. (“Electromagnetic Spectrum,” 2014, para. 1)

The electromagnetic spectrum can be measured in frequencies or in wavelengths. Figure 1 shows wavelengths in meters, ranging from the longest wavelengths (radio waves) to the shortest (gamma rays) (“Electromagnetic Spectrum,” 2014). Visible light, which is a band of colors from red to violet, is the only portion of the spectrum that can be seen by the human eye. As the wavelength decreases, the frequency increases, with gamma rays having the highest frequency.

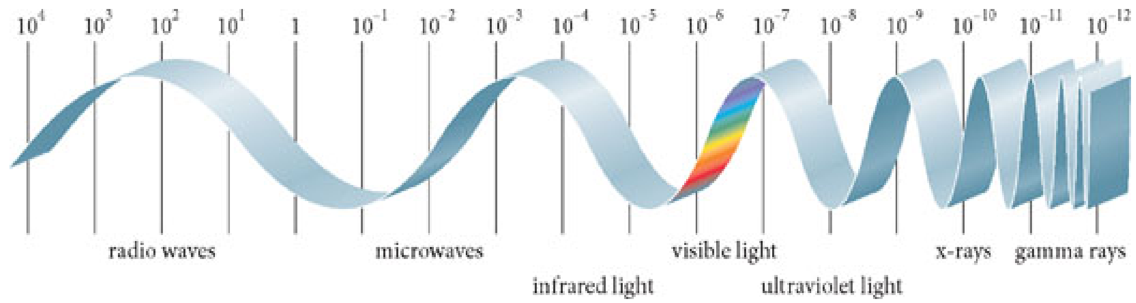

Figure 1. Visual representation of the electromagnetic spectrum. Source: “Electromagnetic Spectrum” (2014).

D. USE OF THE ELECTROMAGNETIC SPECTRUM

The EMS is used in various ways depending on the wavelength. The longer wavelengths, called radio waves, are what people hear daily in radio broadcasts, hand-held radios, and human speech. Most military radio communications occur within this band of frequencies. Military operations utilize the different segments of the radio frequency band for various applications, depending on the wavelength’s transmission properties.

- High Frequency (HF) waves, those between 2 MHz and 30 MHz, (United States Marine Corps [USMC], 2001) are used for over-the-horizon communications. HF waves are able to bounce off the ionosphere, which make them ideal for long-haul communications; but, noise and interference limit their use (Keller, 2002).

- Very High Frequency (VHF) waves range from 30 MHz to 300 MHz (USMC, 2001), and are the most commonly used frequency band in the military. Most tactical, ground-based, line-of-sight communications utilize the VHF band of frequencies.

- Ultra High Frequency (UHF) waves and Microwaves, which range between 300 MHz and 300 GHz, are most often associated with cellular telephones and wireless internet use. The military uses frequencies within this range for air-to-air communications as well as air-to-ground communications (USMC, 2001).

- Infrared (IR) waves, with frequency between 300 GHz and 430 THz, (Liew, 2001) are also used in communication devices. TV remotes, as well as many computer peripherals, operate within this area of the EMS. The military uses frequencies within this band to enable night vision. Signaling devices, as well as night running headlights on vehicles, use IR waves to illuminate objects when viewed through night vision devices.

- Visible light, with frequency between 430 THz to 770 THz (Liew, 2001), is the region of the EMS that the human eye can see. Different frequencies within this band of the EMS make up all the visible colors in the spectrum. Combinations of these frequencies of light give us the world of colors we see today.

Beyond these longer wavelengths are several shorter wavelengths, Ultraviolet, X-ray and Gamma, which have many other uses within the military beyond communications. The focus of this thesis will be on frequencies that fall within the radio and microwave regions of the EMS.

E. SENSING TECHNIQUES

There are many ways to sense the energy being emitted within the EMS. For instance, while the human eye can only sense things within the visible light spectrum, a Geiger Counter can sense energy within the X-ray and gamma region of the EMS ("Geiger counter," 2014).

A cellular telephone is an example of a device that has a built-in sensor able to sense the local surroundings to give a person information about the EMS, most commonly which wireless access points are available. When a cellphone searches for local wireless internet connections, it scans the environment for frequencies within a specific range, in this case 2.4 GHz and 5 GHz. Additionally, the radio in a car is a sensor: it receives radio waves and translates that energy into the talk show or music on the station. For the purposes of this thesis, a spectrum analyzer was the best device to fulfill the requirements of sensing and output display due to the fact that

> Spectrum analyzers are widely used within the electronics industry for analyzing the frequency spectrum of radio frequency, RF and audio signals. Looking at the spectrum of a signal they are able to reveal elements of the signal, and the performance of the circuit producing them that would not be possible using other means. Spectrum analyzers are able to make a large variety of measurements and this means that they are an invaluable tool for the RF design development and test laboratories, as well as having many applications for specialist field service. (Pool, n.d.)

A spectrum analyzer will provide the required measurements of signal strength and bearing to signal. Signal strength and bearing to signal are requisite variables for the calculation of emitter location. Because a spectrum analyzer can accurately sense these variables, they will be considered known variables for input into a mathematical algorithm.

F. STANDARDS ORGANIZATIONS

The EMS is not owned by any entity. Every nation has access to the EMS and, as a result, organizations have been formed over the years to provide oversight. Two scientific organizations oversee the frequency allocations within, and publish guidance on the use of, the EMS: the International Telecommunications Union (ITU) and Institute of Electrical and Electronics Engineers (IEEE) ("ITU is the United Nations," 2018; "IEEE at a glance," 2018). The North Atlantic Treaty Organization has also published guidance on the allocation of frequencies within the EMS. In addition, each country has its own internal regulations for the use of specific frequencies within its borders. Using the guidance of the international community, the Federal Communications Commission (FCC), along with the National Telecommunications and Information Administration, oversees frequency use and allocations within the United States (“About the FCC,” 2018).

1. International Telecommunications Union (ITU)

The ITU is responsible for tracking and assigning satellite orbits, allocating the radio spectrum for the globe and ensuring technologies around the world seamlessly interconnect (ITU, n.d.). ITU.int also states that the ITU consists of 193 Member states and 700 technology companies that meet every four to six years to discuss advancements in communications technologies and their impact upon the world’s populations. These forums facilitate the development and publishing of new standards for the international community to adopt.

Currently, the ITU divides the spectrum into 15 bands. Each band has an applicable number assigned, as well as the frequency ranges within the designated band. Figure 2, from the most recent forum in 2015, shows the updated frequency bands.

TABLE 1

Band number	Symbols	Frequency range (lower limit exclusive, upper limit inclusive)	Corresponding metric subdivision	Metric abbreviations for the bands
3	ULF	300-3 000 Hz	Hectokilometric waves	B.hkm
4	VLF	3-30 kHz	Myriametric waves	B.Mam
5	LF	30-300 kHz	Kilometric waves	B.km
6	MF	300-3 000 kHz	Hectometric waves	B.hm
7	HF	3-30 MHz	Decametric waves	B.dam
8	VHF	30-300 MHz	Metric waves	B.m
9	UHF	300-3 000 MHz	Decimetric waves	B.dm
10	SHF	3-30 GHz	Centimetric waves	B.cm
11	EHF	30-300 GHz	Millimetric waves	B.mm
12		300-3 000 GHz	Decimillimetric waves	B.dmm
13		3-30 THz	Centimillimetric waves	B.cmm
14		30-300 THz	Micrometic waves	B.µm
15		300-3 000 THz	Decimicrometric waves	B.dµm

NOTE 1 – "Band number N" extends from 0.3×10^N to 3×10^N Hz.

NOTE 2 – Symbols: Hz: hertz
k: kilo (10^3), M: mega (10^6), G: giga (10^9), T: tera (10^{12})
µ: micro (10^{-6}), m: milli (10^{-3}), c: centi (10^{-2}), d: deci (10^{-1})
da: deca (10), h: hecto (10^2), Ma: myria (10^4).

NOTE 3 – This nomenclature, used for designating frequencies in the field of telecommunications, may be extended to cover the ranges shown below, as is proposed by the International Union of Radio Science (URSI) (see Table 2).

TABLE 2

Band number	Symbols	Frequency range (lower limit exclusive, upper limit inclusive)	Corresponding metric subdivision	Metric abbreviations for the bands
–1		0.03-0.3 Hz	Gigametric waves	B.Gm
0	ELF	0.3-3 Hz	Hectomegametric waves	B.hMm
1		3-30 Hz	Decamegametric	B.daMm
2		30-300 Hz	Megametric	B.Mm

Figure 2. Frequency band allocations by the ITU. Source: International Telecommunications Union (2015).

2. Institute of Electrical and Electronics Engineers Standards

The IEEE creates standards for international adherence in the development of equipment that operate in the EMS. As posted on the IEEE official website:

> IEEE is a leading developer of international standards that underpin many of today's telecommunications, information technology, and power-generation products and services. Often the central source for standardization in a broad range of emerging technologies, the IEEE Standards Association has a portfolio of over 1,300 standards and more than 600 standards under development. This includes the prominent IEEE 802® standards for local, metropolitan, and other area networks, including Ethernet and Wireless LAN (commonly referred to as Wi-Fi). (IEEE, n.d.)

The international community also adapts IEEE standards in the development of technologies that use the EMS. The IEEE currently consists of over 423,000 members in 160 counties (IEEE, n.d.), all of whom influence the development of communications equipment throughout the world. Adhering to the standards set forth by IEEE enables systems spread across the globe to communicate with each another and to integrate into a worldwide network.

The international table shown in Figure 3 presents the standards for frequency allocations within the EMS according to IEEE. It is important to note that IEEE further differentiates the frequency bands into regions for radar use.

International table				
Band designation	Nominal frequency range	Specific frequency ranges for radar based on ITU assignments (see Notes 1, 2)		
		Region 1	Region 2	Region 3
HF	3–30 MHz	(Note 3)		
VHF	30–300MHz	None	138 –144 MHz 216– 225 MHz (See Note 4)	223-230 MHz
UHF	300–1000 MHz (Note 5)	420–450 MHz (Note 4) 890–942 MHz (Note 6)		
L	1–2 GHz	1215–1400 MHz		
S	2–4 GHz	2300–2500 MHz		
		2700–3600 MHz	2700–3700 MHz	
C	4–8 GHz	4200– 4400 MHz (Note 7)		
		5250–5850 MHz	5250–5925 MHz	
X	8–12 GHz	8.5–10.68 GHz		
Ku	12–18 GHz	13.4–14 GHz		
		15.7–17.7 GHz		
K	18–27 GHz	24.05–24.25 GHz	24.05–24.25 GHz 24.65–24.75 GHz (Note 8)	24.05–24.25 GHz
Ka	27–40 GHz	33.4–36 GHz		
V	40–75 GHz	59–64 GHz		
W	75–110 GHz	76–81 GHz		
		92–100 GHz		
mm (Note 9)	110–300 GHz	126–142 GHz		
		144–149 GHz		
		231–235 GHz 238–248 GHz (Note 10)		

Figure 3. Frequency allocations designated by IEEE standards.
Source: IEEE (2003).

3. FCC Standards

For guidance on the use of the EMS in the United States, the federal government established the FCC in 1934 in order to

> regulate interstate and international communications by radio, television, wire, satellite, and cable in all 50 states, the District of Columbia and U.S. territories. An independent U.S. government agency overseen by Congress, the Commission is the federal agency responsible for implementing and enforcing America’s communications laws and regulations. (FCC, n.d., para. 1)

The FCC, in conjunction with the National Telecommunications and Information Administration, oversees the allocation of both federal and civil frequency space. The Office of Spectrum Management is responsible for the Federal Government’s use of the EMS (“Office of Spectrum Management,” 2011).

Appendix A, “FCC Online Table of Frequency Allocations,” is a sample listing of all allocated frequencies within the spectrum. The document lays out, in detail, that for which each frequency band can be used. These guidelines also lay out conflicts and cross-allocations with other countries. This information will enable a person match a specific frequency with its intended use and device generating the signal. The FCC table of allocations will also aid in the classification of frequencies in other countries because it includes the international table of allocations by region. Figure 4 and 5 are examples of the FCC regulations allocating frequency use within the EMS. From Figure 5 one can determine that broadcast from 614 MHz to 849 MHz will be for mobile use. Investigating the operating parameters of cellular telephones in a geographical region can help determine the exact frequencies those telephones use.

Table of Frequency Allocations			456-894 MHz (UHF)		Page 29
International Table			United States Table		FCC Rule Part(s)
Region 1 Table	Region 2 Table	Region 3 Table	Federal Table	Non-Federal Table	

Figure 4. FCC table of frequency header. Source: FCC Online Table (2018).

	614-698 BROADCASTING Fixed Mobile 5.293 5.309 5.311A		614-698	614-698 FIXED MOBILE NG5 NG14 NG33 NG115 NG149	RF Devices (15) Wireless Communications (27) LPTV, TV Translator/Booster (74G) Low Power Auxiliary (74H)
5.149 5.291A 5.294 5.296 5.300 5.304 5.306 5.311A 5.312 5.312A	698-806 MOBILE 5.313B 5.317A BROADCASTING Fixed		698-758	698-758 FIXED MOBILE BROADCASTING NG159	Wireless Communications (27) LPTV and TV Translator (74G)
			758-775	758-775 FIXED MOBILE NG34 NG159	Public Safety Land Mobile (90R)
790-862 FIXED MOBILE except aeronautical mobile 5.316B 5.317A BROADCASTING			775-788	775-788 FIXED MOBILE BROADCASTING NG159	Wireless Communications (27) LPTV and TV Translator (74G)
			788-805	788-805 FIXED MOBILE NG34 NG159	Public Safety Land Mobile (90R)
	5.293 5.309 5.311A		805-806	805-806 FIXED MOBILE BROADCASTING NG159	Wireless Communications (27) LPTV and TV Translator (74G)
	806-890 FIXED MOBILE 5.317A BROADCASTING		806-809	806-809 LAND MOBILE	Public Safety Land Mobile (90S)
			809-851	809-849 FIXED LAND MOBILE	Public Mobile (22) Private Land Mobile (90)
				849-851 AERONAUTICAL MOBILE	Public Mobile (22)
5.312 5.314 5.315 5.316 5.316A 5.319			851-854	851-854 LAND MOBILE	Public Safety Land Mobile (90S)
862-890 FIXED MOBILE except aeronautical mobile 5.317A BROADCASTING 5.322 5.319 5.323	5.317 5.318	5.149 5.305 5.306 5.307 5.311A 5.320	854-890	854-894 FIXED LAND MOBILE US116 US268	Public Mobile (22) Private Land Mobile (90)

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Figure 5. FCC table of frequencies for a band used by cellular telephones. Source: FCC Online Table (2018).

Along with prescribing the use of all frequencies, the FCC also prohibits transmission over certain ranges. Figure 6 displays the restricted frequencies. Knowing the restricted frequencies will enable the filtering of erroneous inputs that may diminish the accuracy of determining emitter location. If a persistent transmission is detected within one of the restricted bands, the locations of the signal source could be highlighted during the triangulation and plotting of the algorithm to alert the user to suspicious activity.

5.340 All emissions are prohibited in the following bands:

1400-1427 MHz,
2690-2700 MHz, except those provided for by
No. 5.422,
10.68-10.7 GHz, except those provided for by
No. 5.483,
15.35-15.4 GHz, except those provided for by
No. 5.511,
23.6-24 GHz,
31.3-31.5 GHz,
31.5-31.8 GHz, in Region 2,
48.94-49.04 GHz, from airborne stations
50.2-50.4 GHz[2],
52.6-54.25 GHz,
86-92 GHz,
100-102 GHz,
109.5-111.8 GHz,
114.25-116 GHz,
148.5-151.5 GHz,
164-167 GHz,
182-185 GHz,
190-191.8 GHz,
200-209 GHz,
226-231.5 GHz,
250-252 GHz.

Figure 6. FCC prohibited emissions bands. Source: FCC Online Table (2018).

The regulations that guide EMS use enable an observer to observe a frequency and deduce its intended use from the frequency band in which the signal is operating. In order for companies to produce devices that integrate into global communications systems, they must adhere to standards set forth by the international community. Regarding counterinsurgency operations, almost all IEDs are adaptations of civilian technology. RCIEDs that use cellular telephones as triggers are an example of adapting civilian technology to a military purpose. Barring systems specifically designed by conventional nation-state actors to operate in time of conflict, all other conventional devices will adhere to these standards, which enable the classification and identification of transmitting devices.

G. FRIIS EQUATION

As stated in Siwiak and Bahreini's (2007) textbook on radio wave propagation, "basic free space propagation attenuation is due to the geometric spherical expansion of waves, so attenuation is inversely proportional to the distance squared" (p. 88). Sergey A.

Schelkunoff and Harald T. Friis mathematically characterized free space propagation of waves in a medium through the Friis transmission equation.

The Friis transmission equation, Equation 1, determines the distance from the transmitting source to the receiving source based on measured, known, and derived inputs.

$$P_r = P_t G_t G_r / (4\pi(d / \lambda))^2 \qquad (1)$$

P_r = Power received (Watts)

P_t = Power transmitted (Watts)

G_t = Gain of transmitting antenna

G_r = Gain of receiving antenna

d = distance (m)

λ = wave length (m)

Equation 1. Friis transmission formula. Source: Siwiak and Bahreini (2007).

Mathematically taking the power received (P_r) at the sensor's location, users can determine the approximate distance to the transmitting device. By knowing enough about the operational characteristics of devices that transmit at particular frequencies, variables used within Friis transmission formula can be derived.

III. METHODOLOGY

This thesis uses open source information gathering to derive the variable input, power transmitted, for the Friis transmission equation in order to formulate a mathematical algorithm. Combining the features of direction-finding spectrum analyzers with the Friis equation mathematical algorithm allows one to determine the distance from the point of reception to the emitting cellular device. The outputs of the algorithm can be input into a mapping system for practical use by the warfighter to gain situational awareness of the operating environment.

A. FRIIS EQUATION VARIABLE DETERMINATION

In order for a mathematical algorithm to operate effectively, the correct inputs must either be collected, known, or derived. From the Friis equation shown in Equation 1, there are six variables to consider. Five of the six variables are either known or collected from equipment. Power transmitted from the emitting cellular telephone is an unknown variable that must be derived. This thesis analyzes a new method of deriving this unknown variable.

1. Power Transmitted

As seen in the previous section, the FCC controls and allocates frequencies for specific uses. Knowing what each frequency is used for will enable the classification of devices transmitting at those particular frequencies. All transmitting devices are registered with the FCC and given a FCC ID. The FCC database, which files all requests for new devices, states,

> An FCC ID is a unique identifier assigned to a device registered with the United States Federal Communications Commission. For legal sale of wireless devices in the US, manufacturers must:
>
> - Have the device evaluated by an independent lab to ensure it conforms to FCC standards,
> - Provide documentation to the FCC of the lab results,
> - Provide User Manuals, Documentation, and Photos relating to the device, or

- Physically label the device with the unique identifier provided by the FCC (upon approved application). (Federal Communications Commission, 2018)

Most counties control and allocate their frequencies for specific uses much like the FCC. China uses the China Ministry of Industry and Information Technology (CMIIT); South Korea uses the Ministry of Science, ICT and Future Planning (MSIP); and Brazil uses the Agency of National Telecommunications to register and control their devices (Federal Communications Commission, 2018). All these databases can be searched at FCCid.io. Knowing that major markets control their spectrum much like the FCC enables the approximation of most cellular and other transmitting devices. As with most emitting devices, they rely upon connecting to a larger network; the ability to integrate into that network, except for specific military-use equipment, requires compliance with applicable regulations.

Entering the FCC ID of a device into the database at fccid.io will yield information about the device which can be used to derive the power transmitted (P_t) variable for input into the Friis equation. Data contained in the database includes manufacturer, frequency ranges, and power output on each of the frequencies. Pulling a sample of the population and analyzing output characteristics of cellular telephones will enable the approximation of power output at operating frequencies for cellular telephones. Figures 7–9 list the operating parameters for an iPhone X by frequency and power output at that frequency.

Most cellular telephones have multiple channels that broadcast at the same frequency. Having multiple channels at the same frequency allows telephones to transition between cellular towers without a break in transmission. The Same information was pulled for each cellular telephone in the sample set and entered into

Frequency Range	Power Output
13.56-13.56 MHz	
699-716 MHz	66 mW
699-716 MHz	68 mW
699-716 MHz	56 mW
704-716 MHz	55 mW
704-716 MHz	68 mW
704-716 MHz	56 mW
777-787 MHz	76 mW
777-787 MHz	62 mW
777-787 MHz	63 mW
814-824 MHz	83 mW
814-824 MHz	65 mW
814-824 MHz	71 mW
816-824 MHz	83 mW
824-849 MHz	144 mW
824-849 MHz	88 mW
824-849 MHz	85 mW
824-849 MHz	89 mW
824-849 MHz	72 mW
824-849 MHz	76 mW
1.71-1.755 GHz	24 mW

Figure 7. Operating parameters for IPhone X. Source: FCC (2018).

1.71-1.78 GHz	174 mW
1.71-1.78 GHz	178 mW
1.85-1.91 GHz	253 mW
1.85-1.91 GHz	253 mW
1.85-1.91 GHz	257 mW
1.85-1.91 GHz	214 mW
1.85-1.91 GHz	219 mW
1.85-1.915 GHz	251 mW
1.85-1.915 GHz	209 mW
1.85-1.915 GHz	224 mW
2.305-2.315 GHz	135 mW
2.305-2.315 GHz	158 mW
2.305-2.315 GHz	129 mW
2.402-2.48 GHz	106 mW
2.402-2.48 GHz	110 mW
2.412-2.472 GHz	942 mW
2.496-2.69 GHz	355 mW
2.496-2.69 GHz	288 mW
2.496-2.69 GHz	295 mW
2.496-2.69 GHz	251 mW
2.496-2.69 GHz	191 mW
2.496-2.69 GHz	204 mW
2.5-2.57 GHz	251 mW

Figure 8. Operating parameters for IPhone X (continued). Source: FCC (2018).

2.496-2.69 GHz	355 mW
2.496-2.69 GHz	288 mW
2.496-2.69 GHz	295 mW
2.496-2.69 GHz	251 mW
2.496-2.69 GHz	191 mW
2.496-2.69 GHz	204 mW
2.5-2.57 GHz	251 mW
2.5-2.57 GHz	335 mW
2.5-2.57 GHz	302 mW
2.5-2.57 GHz	200 mW
2.5-2.57 GHz	204 mW
5.18-5.24 GHz	174 mW
5.26-5.32 GHz	175 mW
5.5-5.72 GHz	175 mW
5.745-5.825 GHz	281 mW

Figure 9. Operating parameters for IPhone X (continued). Source: FCC (2018).

The power transmission characteristics of 30 of the most popular cellular telephones in production were collected; Table 1 presents a list of cellular telephones used in this study. Power transmission for each device was pulled from the FCC.io database and entered into an Excel spreadsheet for analysis.

Table 1. List of cellular telephones used in analysis

Manufacturer	Device Name	FCC ID
Apple	IPhone X	BCG-E3161A
Apple	IPhone 8	BCG-E3159A
Apple	IPhone 7	BCG-E3091A
Apple	IPhone SE	BCG-E2945A
Apple	IPhone 6s	BCG-E2946A
Apple	IPhone 6	BCG-E2816A
Apple	IPhone 5s	BCG-E2642A
Apple	IPhone 5c	BCG-E2644A
Apple	IPhone 5	BCG-E2599A
Apple	IPhone 4s	BCG-E2430A
Apple	IPhone 4	BCG-E2380A
Samsung	Note 3	A3L-SMN9005
Samsung	Note 4	A3L-SMN9100
Samsung	Note 5	A3L-SMN9200
Samsung	Note 7	A3L-SMN9300
Samsung	Note 8	A3L-SMN9500
Samsung	Galaxy S9	A3L-SMG9600
Samsung	Galaxy S8	A3L-SMG9500
Samsung	Galaxy S7	A3L-SMG9300
Samsung	Galaxy S6	A3L-SMG9200
Samsung	Galaxy S5	A3L-SMN900A
Samsung	Galaxy S4	A3L-GTI9500
Google	Pixel 2	NM8G-011A
Google	Pixel	NM8G-2PW4100
LG	G6	ZNF-H871
LG	G5	ZNF-H820
LG	G4	ZNF-H815
Motorola	Moto E	IHD-T56QC8
Motorola	Moto X	IHD-T56QA1
Kyocera	DuraForce	V65-E6560

The transmission characteristics data contained in the FCC database helped determine the operational frequency ranges. The power transmitted by each device on each uniquely identifiable channel was input into the spreadsheet. Appendix B contains all the data that was pulled for the 30 cellular telephones and their respective operating characteristics. The consolidation of the operating characteristics revealed a trend of operating frequencies. Table 2 contains the breakdown of all the bands in which cellular telephones transmit. Cross-referencing known operating frequency bands and FCC regulatory guidelines validates the method of classifying devices based on operating frequency.

Table 2. Operating frequencies of cellular telephones

Operational Frequency Ranges
699 MHz – 716 MHz
814 MHz – 849 MHz
1.71 GHz - 1.78 GHz
1.85 GHz – 1.915 GHz
2.305 GHz – 2.48 GHz
2.504 GHz – 2.69 GHz
5.18 GHz – 5.24 GHz
5.26 GHz – 5.32 GHz
5.5 GHz – 5.826 GHz

During the collection process, the transmission properties associated with early class 1 and 2 Bluetooth devices was discarded and, therefore, not factored into the transmission characteristics at those operating frequencies. Bluetooth devices are intended to operate within short-range ad hoc networks, called Piconets. During the early years of development, class 1 and 2 Bluetooth devices did not transmit enough power at those operational frequencies to have the necessary effective range for RCIEDs ("Bluetooth," 2016). More modern and advanced devices that integrate Bluetooth class 3 and 4 were factored into the transmission characteristics at those operating frequencies due to their increased power output, which extended the Bluetooth range to over 100 ft.

Upon the identification of a signal, the algorithm would be able to reference the data in Appendix B. By comparing the received signal frequency to that on the data table, one would be able to obtain the average power transmitted at that frequency. Power transmitted would then be used in the Friis equation to calculate the range to the emitter.

2. Gain of Transmitting Antenna

Due to their unpredictable locations relative to the receiving tower, cellular telephones utilize isotropic, omnidirectional antennas. Cellular towers, however, use both directional and omnidirectional antennas based upon location (Faruque, 1996). Though directional antennas are used on cellular towers, omnidirectional antennas are the most widely used to support the cell structure of cellular telephone networks. This thesis assumes the use of isotropic, omnidirectional cellular tower antennas due to their prevalence in support of most cellular tower network structures. The gain of an isotropic, omnidirectional antenna is 1 dBi.

3. Obtaining Known Variables

The gain of the receiving antenna (G_r) will be published in the specifications manual of the spectrum analyzer in use and will be a predetermined input that is known to the operator (Berkeley Varitronics Systems, 2018). Power received (P_r) will be an output by the spectrum analyzer in use. Power received can either be displayed in mW or dBm. For input into the Friis equation, power received will be translated to mW using

$$\mathrm{P_r}(dBm) = 10\log(\mathrm{P_r}/1mW) \qquad (2)$$

Equation 2. Power conversion from mW to dBm. Source: Ulaby and Ravaioli (2015).

An additional output from the spectrum analyzer will be the frequency of the signal received. Frequency can be converted to wavelength by using the relationship

$$Frequency = Speed\, of\ Light / Wavelength \qquad (3)$$

Equation 3. Wavelength and frequency relationship. Source: Ulaby and Ravaioli (2015).

Wavelength will be input into the Friis equation displayed as λ. Equation 4 breaks down the Friis equation into its variables of known and determined yields:

$$P_r = P_t G_t G_r / (4\pi(d / \lambda))^2 \qquad (4)$$

P_r = Output by spectrum analyzer (mW)

P_t = Computed from population sample (mW)

G_t = Isotropic determined to be 1

G_r = Given within the specifications manual of equipment

d = variable being solved for

λ = determined from analyzed frequency

Equation 4. Detailed breakdown of how all the variable inputs for Friis transmission equation are obtained. Source: Siwiak and Bahreini (2007).

One can now determine, mathematically, the distance from the spectrum analyzer to the emitting source by solving for distance using:

$$d = (\lambda \sqrt{P_t G_t G_r / \mathrm{P_r}}) / 4\pi \qquad (5)$$

Equation 5 is the result of solving the Friis transmission equation for distance, which will be used to determine distance from the receiver to the transmitter with the known and derived variable inputs.

B. DIRECTION DETERMINATION PROCESS

Procurement of an off-the-shelf spectrum analyzer would enable the determination of signal strength and direction to received signal. Direction-finding spectrum analyzers, such as the Bumble Bee LX Spectrum Analyzer from Berkley Varitronics Systems and the SignalShark from Narda, output the necessary variables of signal strength, signal frequency and are equipped with the appropriate direction-finding antenna, as seen in Figures 10 and 11, bearing to signal (Narda Safety Test Solutions, 2018).

Figure 10. Yellow Jacket System with direction finding antenna. Source: Berkeley Varitronics Systems (2018).

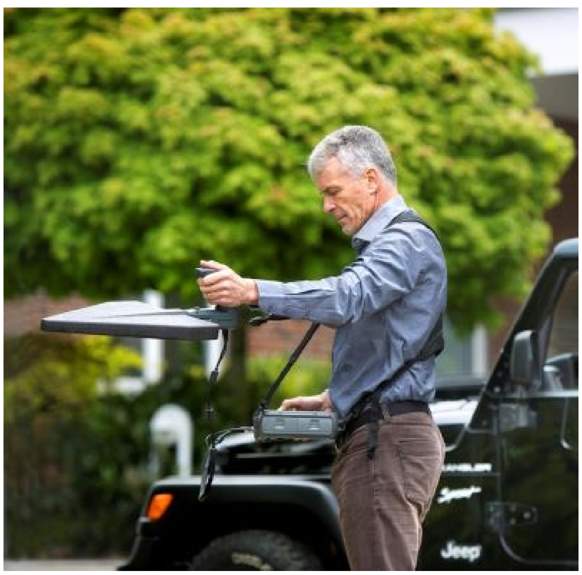

Figure 11. SignalShark direction finding antenna. Source: Narda Safety Test Solutions (2018).

Coupling received signal direction with the mathematically computed signal distance, one can plot an approximate location of the emitter relative to the receiver, as shown in Figure 12.

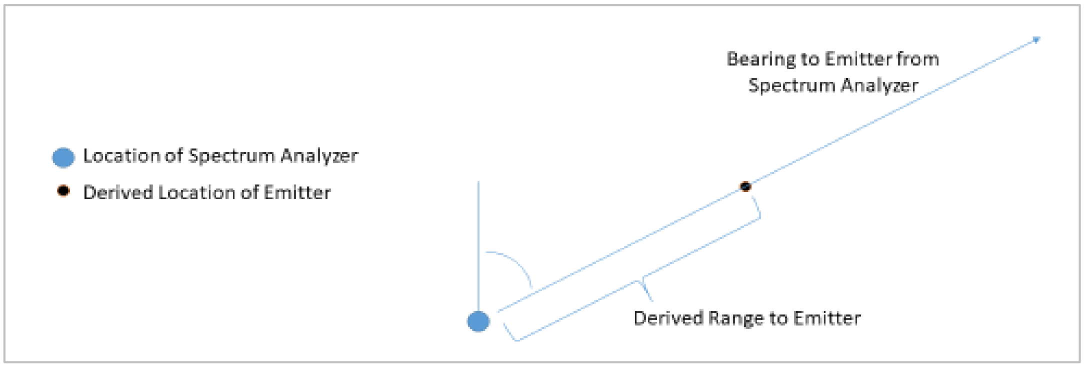

Figure 12. Depiction of how an emitter's location is derived from range and bearing

C. SOFTWARE INTERFACE FOR APPLYING THE TRACING ALGORITHM

Both the Bumble Bee and the Shark systems interface with computers and output their readings into formats for computational analysis. Applying the Friis-based mathematical formula to the outputs of the various systems can be accomplished by running them through a preprogrammed script executed in a computing code such as Python. Python can be run on many platforms, including mobile devices. QPython – Python on Android is an example of a simple application that can execute python code on any Android device (QPython, 2017). The application is free of cost and, since it executes the code inside of a shell, the means of importing the data could be programmed into the script. The algorithm would be able to digest and process the inputs of the spectrum analyzers and output a calculated distance and direction. GPS data for the current location of the spectrum analyzer can also be input in the Python algorithm, enabling the trigonometric calculation of location relative to the receiving unit to be transformed into .gpx or .loc format. Importing the .gpx or .loc into a mapping system would create a graphical display of emitting nodes within an area.

D. MAPPING SYSTEMS

Various mapping software suits exist that can display the output of an algorithm in a .gpx or .loc file format, including current programs of record, but many are limited in their ability to support the development of a handheld device for the squad to utilize.

Current military mapping programs of record include Northrop Grumman Corporation's Force XXI Battle Command Brigade and Below (FBCB2), also known as Blue Force Tracker, and General Dynamics' Command Post of the Future (CPOF). Northrup Grumman first developed FBCB2 in the early 2000s, and there have since been more than 85,000 systems deployed ("Next-generation FBCB2," 2009). FBCB2 is the most widely used command and control system in the military. FBCB2 has undergone a series of upgrades since its inception, and in 2009 the program transitioned to a secret classified system ("Next-generation FBCB2," 2009). An interface connected to FBCB2 would, thereby, also be sensitive and controlled, which would hinder availability and ease of use. The current version of FBCB2 also requires a continuous power source for the display and the satellite receiver. Both the classification and power requirements of the FBCB2 render it infeasible for the development of a handheld device.

The design premise of General Dynamics' CPOF software was to display critical events, which would enable troops to visualize the battlefield and coordinate missions. CPOF is a user-friendly application that runs on General Dynamics' CoMotion software suit (General Dynamics Mission Systems, n.d.). Interfacing into this system would require thorough knowledge of the CoMotion platform, as well as increased computing power to process all the graphical interface tools CPOF utilizes. For these reasons, CPOF is not currently supported on handheld devices.

The military also utilizes Google software for much of its battle-tracking. The military uses both Google Earth and classified Google Earth for the purpose of command and control. The open architecture of Google Earth and the ability to download a geographical region onto a handheld device are ideal for mapping in a local area. As mentioned previously, computer coding languages, such as Python, C+ or R, can process raw track data into a usable file format, such as .gpx or .loc, which can then be imported into Google Earth to produce a representative map of said data (Google, n.d.).

E. FLOW OF INFORMATION DIAGRAM

Figure 13 depicts how information from the various systems would be exchanged. Sensing data from the spectrum analyzer and location data from a GPS will be used to generate values for the algorithm. The signal frequency will be compared to the predetermined table of known power outputs at that frequency to derive power transmitted. All variables can be cycled through the mathematical algorithm to derive range to the emitting device. Inputting current location, range to the device and the bearing to the device into a trigonometric calculation will result in the known location of the emitter. Emitter location can be displayed using mapping software, enabling the warfighter to make decisions based on real-time situational awareness. Ultimately, this process proposes the means to defeat, rather than merely avoid, the RCIED threat.

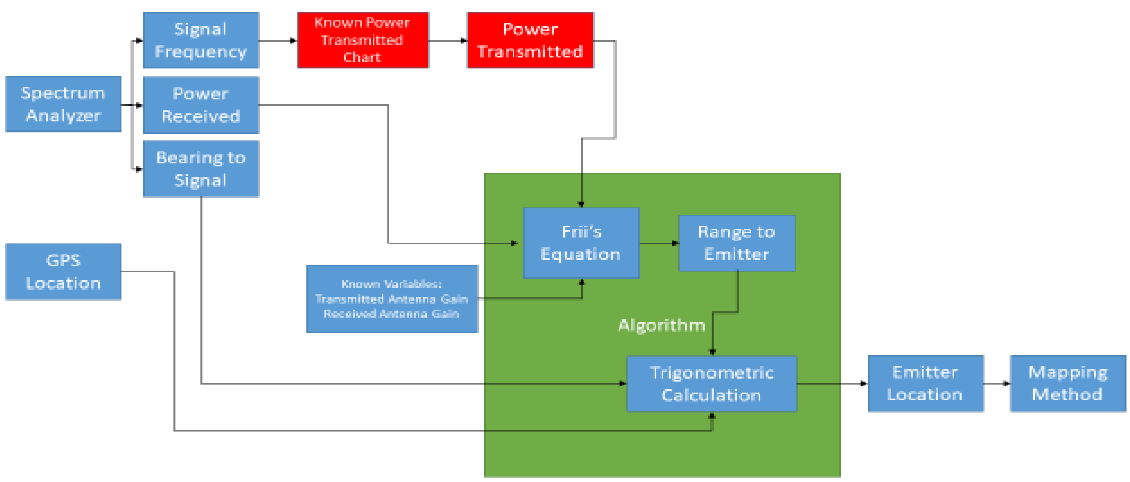

Figure 13. Flow of information and derivations

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IV. FINDINGS

A. OPEN SOURCE INFORMATION ANALYTICS

1. Analysis of Entire Population

Each operating frequency band was analyzed independently to ensure each operating mode, standby mode, active mode, WiFi and Bluetooth 2.4 GHz and WiFi 5Ghz did not affect the transmitted power averages of the other frequency bands.

Average power for the entire frequency band was calculated and is displayed in Table 3.

Table 3. Average power of each frequency band

Operational Frequency Ranges	Average Power of Entire Band
699 MHz – 716 MHz	60.83 mW
814 MHz – 849 MHz	154.51 mW
1.71 GHz - 1.78 GHz	227.20 mW
1.85 GHz – 1.915 GHz	358.88 mW
2.305 GHz – 2.48 GHz	205.18 mW
2.504 GHz – 2.69 GHz	280.48 mW
5.18 GHz – 5.24 GHz	62.03 mW
5.26 GHz – 5.32 GHz	60.79 mW
5.5 GHz – 5.826 GHz	71.45 mW

The standard deviation for the entire band was calculated based on the power transmitted from the 30 cellular telephones and is displayed in Table 4.

Table 4. Standard Deviation of the frequency bands

Operational Frequency Ranges	Standard Deviation
699 MHz – 716 MHz	26.98 mW
814 MHz – 849 MHz	238.70 mW
1.71 GHz - 1.78 GHz	148.28 mW
1.85 GHz – 1.915 GHz	324.33 mW
2.305 GHz – 2.48 GHz	230.93 mW
2.504 GHz – 2.69 GHz	375.13 mW
5.18 GHz – 5.24 GHz	47.46 mW
5.26 GHz – 5.32 GHz	47.35 mW
5.5 GHz – 5.826 GHz	60.88 mW

From the data analysis, one can see that there is a large disparity in the transmitting powers of the cellular devices within the frequency bands. The large standard deviation for the power transmitted would not make this method of deriving an unknown variable viable. Further analysis would need to be conducted to determine the cause of such a large disparity in the power transmission values of the individual devices.

2. Analysis of Population Considering Generation of Development

After closely analyzing the operating parameters of each cellular telephone, it became apparent that another variable needed to be considered. Advancements in technology over the past 7 years have drastically changed the operating parameters of the cellular telephone devices considered in the data set. Apple released the iPhone 4 in 2010, at which time it had a maximum power transmitted of 1660 mW. With the advancements in efficiency and the deployment of wider coverage networks, the iPhone X, released in 2017, operates at 144 mW while transmitting at the same frequency Federal Communications Commission, 2018). The large disparity in operating parameters, due to the evolution of technological generations, does not allow the extrapolation of accurate operating characteristics from the sample set as a whole.

Grouping the cellular telephones into technology generations results in a more accurate extrapolation of average power transmitted, as show in Table 5. The generational power demands from third generation (3G) to fourth generation (4G) devices is the largest factor to consider in the data set.

Table 5. Example of power transmitted difference across generations

Operational Frequency Ranges	IPhone 4 (3G device)	IPhone 5 (4G device)
699 MHz – 716 MHz	Does not operate	223.75 mW
814 MHz – 849 MHz	866.42 mW	174.28 mW
1.71 GHz - 1.78 GHz	Does not operate	603.51 mW
1.85 GHz – 1.915 GHz	902.38 mW	457.25 mW
2.305 GHz – 2.48 GHz	337.00 mW	Does not operate
2.504 GHz – 2.69 GHz	Does not operate	Does not operate
5.18 GHz – 5.24 GHz	Does not operate	Does not operate
5.26 GHz – 5.32 GHz	Does not operate	Does not operate
5.5 GHz – 5.826 GHz	Does not operate	Does not operate

Further data analysis broke the sample of cellular telephones into generational categories, presented in Table 6.

Table 6. Cellular telephone breakdown by generation

4th Generations Devices	3rd Generation Devices
Apple IPhone X	Apple IPhone 4s
Apple IPhone 8	Apple IPhone 4
Apple IPhone 7	Samsung Note 3
Apple IPhone 6s	Samsung Note 4
Apple IPhone 6	Samsung Galaxy S4
Apple IPhone SE	
Apple IPhone 5c	
Apple IPhone 5s	
Apple IPhone 5	
Samsung Note 5	
Samsung Note 7	
Samsung Note 8	
Samsung Galaxy S9	
Samsung Galaxy S8	
Samsung Galaxy S7	
Samsung Galaxy S6	
Samsung Galaxy S5	
Google Pixel	
Google Pixel 2	
LG G6	
LG G5	
LG G4	
Motorola Moto E	
Motorola Moto X	
Kyocera DuraForce	

After sorting the data set by correct generation of cellular device, Table 7 shows the average power transmitted. This produced a more accurate representation of the average power transmitted from that class of device.

Table 7. Average power transmitted by generation

Operational Frequency Ranges	4th Generation Cellular	3rd Generation Cellular
699 MHz – 716 MHz	60.86 mW	Does not operate
814 MHz – 849 MHz	112.12 mW	507.26 mW
1.71 GHz - 1.78 GHz	227.20 mW	Does not operate
1.85 GHz – 1.915 GHz	349.65 mW	519.79 mW
2.305 GHz – 2.48 GHz	208.09 mW	178.80 mW
2.504 GHz – 2.69 GHz	299.04 mW	59.25 mW
5.18 GHz – 5.24 GHz	68.88 mW	28.40 mW
5.26 GHz – 5.32 GHz	67.03 mW	28.77 mW
5.5 GHz – 5.826 GHz	79.55 mW	28.40 mW

For increased accuracy, the average power transmitted at each individual frequency, sorted by generation, was calculated in Appendix B. Creating a table in which individual frequencies, rather than frequency ranges, could be referenced will ensure the most accurate approximation for power transmitted at that frequency.

The data analysis proves that it is important to know what types of devices are being used in a given area. Each reference table for power transmitted should be built and tailored to the operating environment in which it will be deployed. Gaining signals intelligence about the current infrastructure and the operating habits of the local populace will be key to developing an accurate power transmission table to extrapolate the unknown variable P_t. The more information that is known about the devices being used by the adversaries, the more accurately the location of the device will be derived from the mathematical algorithm.

B. ANALYSIS OF DIRECTION FINDING CAPABILITIES

Current technology has not progressed far enough in the commercial sector to support multi-channel direction finding in handheld devices. Direction finding in current off-the-shelf systems is limited to single-channel. This means that a person is able to lock onto a single signal of the device and get a bearing to the transmitting source, one transmitting source at a time. Current limitations on the development of direction-finding capabilities of off-the-shelf technologies restrict the ability to conduct field tests within the construct of this thesis. As explained in the previous chapters, the method of locating and mapping transmitting sources is sound but, without further development of off-the-shelf technologies, the proposed ideas remain theoretical.

1. Current Spectrum Analyzers

Current spectrum analyzers are limited in their ability to conduct direction finding. Both the Bumble Bee and Shark systems are able to conduct direction finding with the correct antenna. However, each of the systems has limitations that would preclude them from being able to fully support the scope of this thesis. The Bumble Bee and Shark systems are limited to single-channel direction finding. They can scan an entire range of frequencies to determine the amount of traffic in that band, but can only find the direction to one signal at a time. The process of conducting direction finding with each of the systems is cumbersome and time-consuming. The systems must lock onto each signal and the user must navigate a series of interface menus in order to isolate and determine the direction to a single signal. Isolating and direction finding on both the Bumble Bee and the Shark systems cannot be automated at this time and, therefore, would not support the scope of this thesis.

Another limiting factor for the utility of the Bumble Bee system is the requirement to switch antennas for different frequency bands. A user would have to switch direction-finding antennas three times in order to cover the range of frequencies generated by a cellular telephone. The Bumble Bee system requires 900 MHz, 2.4 GHz and 4.9/5.0 GHz direction-finding antennas to cover the entirety of frequency bands researched in this thesis (Berkeley Varitronics Systems, 2018). Enabling the warfighter to sense the surrounding environment is important, but it must be balanced with utility and ease of use; carrying and installing three types of antennas does not achieve the desired balance. It is important to note that the gain of each antenna (G_t) is listed in the specifications sheet, which would be added to the Friis transmission formula algorithm.

The SignalShark system is more advanced and is able to conduct direction finding using only a single antenna. Using the SignalShark Application Package Antenna Basic Kit, one can conduct direction finding from 400 MHz to 8 GHz in a single antenna. In addition, the SignalShark has direction-finding antennas for 20MHz to 250MHz and 200 MHz to 500 MHz (Narda Safety Test Solutions, 2018). Though the SignalShark has a single antenna that meets the specifications of this thesis, the process of isolating and conducting direction finding on a signal are much like the Bumble Bee system and cannot be automated. The SignalShark is farther along in the development stage than the Bumble Bee for providing direction finding to the user, but has not progressed far enough to effectively and efficiently couple with a mapping algorithm at this time.

2. Multi-channel Direction Finding Research

Research has been conducted into multi-channel direction finding using small antenna arrays. "Phase sensitive direction finding (DF) systems rely on measuring the relative time delay between two or more antennas to make a determination of the direction of the radio emitter" (Mohan, Harrington, Sharpe, Barber, & Babbitt, 2013, p. 241). In 2013, at a IEEE International Topic Meeting on Microwave Photonics, a group of individuals proposed and demonstrated direction finding capabilities with a two-antenna system. The study established that they could "determine the power and direction of all spectrally non-overlapping emitters in an area" (Mohan et al, 2013, p. 241) The study analyzed the phase time delay between each signal received at each antenna. As stated in the study, "The sensitivity of the optical power spectra of the two output ports to the time delay of each resolvable frequency component of the signals enables the determination of energy and direction of each resolvable frequency component of multiple emitters" (Mohan et al., 2013, p. 241). Mohan's study also stated that upon the reception of the signal at each antenna, a post-processing technique was used to estimate the angle of arrival of the signal to each antenna. From the received angle calculation, a direction to the emitter could be determined. The current configuration of the system enabled the group to monitor multiple types of emitters simultaneously across the spectrum.

If Mohan et al.'s research is commercialized in the future, it would meet the requirements of this research and allow for the development of a prototype device.

3. Software Defined Radios

A new and developing technology that could be used to solve the direction-finding shortfall is software defined radio (SDR). A software defined radio, as stated by Arslan and Celebi (2007),

> represents a very flexible and generic radio platform which is capable of operating with many different bandwidths over a wide range of frequencies and using many different modulation and waveform formats. As a result, SDR can support multiple standards (i.e. GSM, EDGE, WCDMA, CDMA2000, Wi-Fi, WiMAX) and multiple access technologies such as Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), Orthogonal Frequency Division Multiple Access (OFDMA), and Space Division Multiple Access (SDMA). (pp. 110–111)

SDR's ability to process a wide range of signals without additional hardware make it a viable platform for integrating into a handheld system.

By incorporating an analog-to-digital converter into the system, the SDR can process signals in the digital domain, either on a computer or internally (Arslan & Celebi, 2007). The ability to process signals digitally can enable the processing of signals from different sources simultaneously. Understanding and implementing the work of Mohan et al. and coupling it with an array of SDRs could lead to a direction-finding solution. Arranging multiple SDRs into an array would enable the post-processing of the signal, in digital form on a computer, to determine the phase angle difference between the received signals and extrapolate a direction to the source of the signal (Mohan et al., 2013). Coupling an SDR array design with the algorithm developed in this thesis could be accomplished by integrating the signal post-processing technique into the computational algorithm.

C. PATH LOSS FACTORS AND ATTENUATION

During the conduct of research and analysis of theory, it was found that there are other losses to consider when calculating distance to emitting source. Throughout this thesis the consideration for determining distance from transmitting source relied upon the use of free space loss of the signal being transmitted. However, there are other types of loss that can affect the signal as it propagates thoughout space. To better understand this theory, the link equation can be analyzed in dBm form, as show in Equation 6.

$$\mathrm{P_r} = \mathrm{P}_t - FSL + G_r + G_t - Attenuation \quad (6)$$

P_r = Power of the received signal in dBm

P_t = Power of the transmitted signal in dBm

G_t = Gain of the transmitting signal in dBi

G_r = Gain of the receiving signal in dBi

FSL= Free space loss in dBm

Attenuation = loss due to outside interference in dBm

Equation 6. Friis equation in dBm form. Source: Michael (2012).

This iteration of the equation uses the same input variables as discussed in the previous chapter, but all units have been converted to dBm. The loss factor of free space is calculated, but if the surrounding area does not consist solely of free space there will be other losses that need to be accounted for in order to get an accurate range to the emitter. Other loss factors to consider are absorption, scattering, reflection, refraction, terrain and vegetation (Alexander, 2009). All of these factors can impede the propagation of radio waves. Impedance is referred to as ‘attenuation’ in reference to radio wave propagation.

1. Environmental Attenuation

a. Attenuation: Small Grove of Trees

ITU – R are recommendations from ITU for the calculations of various things. ITU published recommendations for path loss through a small grove of trees, which is shown in Equation 7. This recommendation was “developed from measurements carried out mainly at UHF as was proposed for cases where either the transmitter or the receiver was near a small (d<400) grove of trees” (Meng, Lee, & Ng, 2009, p. 122).

$$LITU - R = .2 f^{.3} d^{.6} \qquad (7)$$

LITU –R = path loss through a small grove of trees <400m

f = frequency of signal

d = depth of the grove

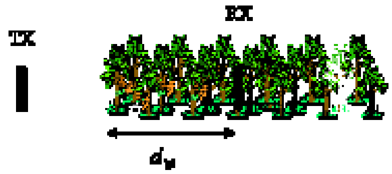
Equation 7. Attenuation through a small grove of trees <400m calculation.
Source: Meng et al. (2009).

b. Attenuation: Single Antenna in Woodlands

ITU – R P.833-3 gives a model for calculating attenuation loss from trees and foliage. Figure 14 displays the case for particular antenna locations that affect the attenuation. These factors can be input into the algorithm to increase the accuracy of emitter location.

International Telecommunications Union (ITU) recommendation P.833-3 gives the following model for calculating the excess loss due to attenuation from trees and foliage.

Case 1: One antenna in the open, the other in the woodlands



$$A_w = A_m \left\{1 - \exp\left(-\frac{\alpha_w d_w}{A_m}\right)\right\}$$

where d_w is the path length in the wooded area and α_w is the attenuation in dB/m for the foliage. The attenuation factor takes on a wide range of values, but can often be approximated by $\alpha_w = 0.2 f_{GHz}$. A_m is the maximum attenuation for one terminal within a specific type and depth of vegetation. For moderate tropical growth (i.e., measurements taken in a park in a tropical climate), in dB:

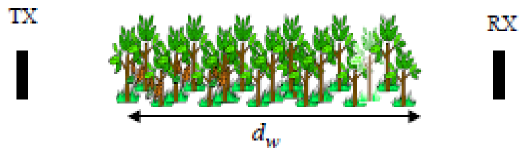
$$A_m = 32.5\left(f_{GHz}\right)^{0.752}, \quad 0.9 \le f_{GHz} \le 1.8$$

Figure 14. One antenna in the open, other antenna located within woodlands. Source: T. Smith (email to author, May 4, 2018).

c. Attenuations: Both Antenna Located outside Woodlands

ITU – R P.833.3’s second antenna location scenario consists of both antennae outside the woodland area. Figure 15 displays the formula for calculating attenuation for this second scenario.

Case 2: Both ends of the link are in the open



Parameter	In Leaf	Out of Leaf
a	0.2	0.16
b	1.27	2.59
c	0.63	0.85
K_o	6.57	12.6
R_f	0.0002	2.1
A_o	10	10

$$A_m = \begin{cases} d_w \alpha_w, & f_{GHz} \le 3 \\ R_\infty d_w + K\left[1 - \exp\left(-\frac{R_o - R_\infty}{K} d_w\right)\right], & f_{GHz} > 5 \end{cases}$$

where $K = K_o - 10\log_{10}\left\{A_o\left[1 - \exp\left(-\frac{A_{\min}}{A_o}\right)\right]\left[1 - \exp\left(-R_f f_{GHz}\right)\right]\right\}$, $R_o = a f_{GHz}$ and $R_\infty = b / f_{GHz}^c$.

Figure 15. Both antenna outside woodlands. Source: T. Smith (email to author, May 4, 2018).

2. Atmospheric Attenuation

Weather can have an effect on the propagation of radio waves. The following sections contain mathematical calculations for the attenuation of common weather conditions that can degrade the free space propagation of radio waves.

a. Attenuation: Rain

Rain is often measured in fall rate, or rain rate. To calculate the attenuation of rain or other forms of precipitation, an observer must be able to estimate the rain rate in the environment. Rain rate is often measured in millimeters per hour. Richards, Scheer and Holm (2010) give a general model for approximating the attenuation of rain, shown in Equation 8. The variables *a* and *b* are based on drop-size distribution models, which can vary across the globe. Figure 16 presents an example of the outputs of a drop-size distribution model that will provide the inputs for the variables *a* and *b*.

$$\alpha = a \cdot r^{b} \quad (8)$$

α = *Rain attenuation*

a and b = Are given by drop-size distribution models

Equation 8. Rain attenuation calculation. Source: Richards et al. (2010).

Frequency (GHz)	a_h	a_v	b_h	b_v
1	0.0000387	0.0000352	0.912	0.880
2	0.000154	0.000138	0.963	0.923
3	0.000650	0.000591	1.121	1.075
6	0.00175	0.00155	1.308	1.265
7	0.00301	0.00265	1.332	1.312
8	0.00454	0.00395	1.327	1.310
10	0.0101	0.00887	1.276	1.264
12	0.0188	0.0168	1.217	1.200
15	0.0367	0.0347	1.154	1.128
20	0.0751	0.0691	1.099	1.065
25	0.124	0.113	1.061	1.030
30	0.187	0.167	1.021	1.000
35	0.263	0.233	0.979	0.963
40	0.350	0.310	0.939	0.929
45	0.442	0.393	0.903	0.897
50	0.536	0.479	0.873	0.868
60	0.707	0.642	0.826	0.824
70	0.851	0.784	0.793	0.793
80	0.975	0.906	0.769	0.769
90	1.06	0.999	0.753	0.754
100	1.12	1.06	0.743	0.744
120	1.18	1.13	0.731	0.732
150	1.31	1.27	0.710	0.711
200	1.45	1.42	0.689	0.690
300	1.36	1.35	0.688	0.689
400	1.32	1.31	0.683	0.684

Figure 16. Drop-size distribution model. Source: Richards et al (2010).

b. *Attenuation: Fog*

For frequencies below 5 GHz the fog attenuation is considered to be negligible, but for frequencies above 5 GHz one must account for attenuation. Equation 9 will calculate the attenuation value for frequencies above 5 GHz.

$$\alpha_{fog}(dB/km) = M(-1.347 + .66 f_0 + (11.152 / f_0) - 0.022 * T) \qquad (9)$$

M = water concentration (g/m^3)

f_0 = frequency (GHz)

T = temperature (°C)

Equation 9. Attenuation calculation for fog. Source: Richards et al. (2010).

Figure 17 lists typical water concentrations for various fog conditions. These values will aid the warfighter in the decision making process, enabling a more accurate estimation of range to the emitting device.

Type	Water Concentrations (g/m^3)	Remarks
Steam fog	0.1–1.0	Results from cold-air movements over warm water
Warm-front fog	0.1–1.0	Evaporation of warm rain falling through cold air, usually associated with the movement of a warm front, under certain humidity, conditions yields a supersaturated air mass at ground level
Radiation fog	0–0.1	Results from radiation cooling of the earth's surface below its dew level
Coastal and inland ground fog	0.1–1.0	Radiation fog of small heights
Valley fog	0.1–1.0	Radiation fog that forms in valleys
Advection fog	0–0.1	Formed by cool air passing over a colder surface
Up-slope fog	0.1–1.0	Results from the adiabatic cooling of air up-sloping terrain

Figure 17. Common water concentrations for fog conditions. Source: Richards et al. (2010).

c. *Attenuation: Snow and Hail*

For calculating the attenuation due to snow, one must determine the rainfall rate of the snow before calculating the attenuation. As stated in Richards et al. (2010), the rainfall rate of snow is a function of mass concentration of snow (g/m^3) and the velocity of snowfall (m/s). Equation 10 calculates rainfall rate, and Figure 18 lists common snow types and their respective input values. Upon computing the value for rainfall rate, Equation 11 can calculate the overall attenuation for the signal.

$$R = Xv \quad (10)$$

R = *Rainfall rate*

X = *Mass concentration of snow* (g/m^3)

V = *Velocity of snowfall*

Equation 10. Rainfall rate calculation. Source: Richards et al. (2010).

Snow Type	Diameter (mm)	Mass (mg)	Fall Velocity (cm/s)
Needle	1.53	0.004	50
Plane dendrite	3.26	0.043	31
Spatial dendrite	4.15	0.146	57
Powder snow	2.15	0.064	50
Rimed crystals	2.45	0.176	100
Graupel	2.13	0.80	180

Figure 18. Common properties of snowfall types. Source: Richards et al. (2010).

$$\alpha_{snow}(dB/km) = 0.00349(R^{1.6}/\lambda^4) + 0.00224(R/\lambda) \quad (11)$$

R=*rainfall rate* (*mm/hr*)

Equation 11. Attenuation for snow calculation. Source: Richards et al. (2010).

d. *Attenuation: Dust*

The attenuation coefficient for dry dust particles can be approximated using Equation 13. As determined by Bruce, Kalinowski and Ashmore (1990), the extinction factor depends on the composition and size of the particles. Therefore, to calculate the extinction factor, an observer would have to approximate the size of the particles in the air, which is show in Equation 12.

$$\in / \rho = 0.222m^2 / g \pm 0.06m^2 / g \quad (12)$$

$\in$ = *Extinction coefficient*

ρ = *Mass of particles per unit volume*

Equation 12. Extinction coefficient calculation. Source: Bruce et al. (1990).

For input into the calculation of attenuation contained in Equation 12, $\in$ is equivalent to η for extinction coefficient inputs.

$$\alpha_{dust}(dB / km) = 4343(M * \eta) \quad (13)$$

M = *particulate concentration* (g/m^3)

η = *extinction coefficient* (m^2/g)

Equation 13. Attenuation for dust calculation. Source: Richards et al. (2010).

D. PATH LOSS IN URBAN IN ENVIRONMENTS

Path loss calculations in an urban environment quickly become more problematic than environmental considerations. Many models have been produced to simulate the effects of urban areas on wave propagation. The most widely accepted are the Urban Hata model, COST (extended) Hata model and the Walfsch-Ikegami model. Mark Alexander's thesis (2009) "Understanding and Predicting Urban Propagation Losses" tested these three models for their accuracy with a predetermined set of input parameters. Alexander (2009) developed an excel tool to test the validity of the various models with controlled inputs to compare their theoretical results with the actual results. In his comparisons, he determined that the Urban Hata model consistently produced results within five to ten percent of the known, most accurate model under various conditions (Alexander, 2009). Incorporating the Urban Hata model into calculations will produce greater accuracy in urban environments.

The computational algorithm can be further refined to include considerations for the surrounding area. Factoring in the path loss due to the surrounding area will enhance the accuracy of the algorithm's ability to compute distance to the emitter.

E. COMPLETE TRACING ALGORITHM

Used many times throughout this thesis, Merriam-Webster defines the term 'algorithm' as "a step-by-step procedure for solving a problem or accomplishing some end especially by a computer" ("Algorithm," n.d., para. 1). This thesis set out to develop an algorithm for plotting the location of cellular telephones to enable warfighters to identify and defeat RCIEDs. Figures 19–24 display the algorithm designed throughout this process, and figure 25 presents an accompanying legend.

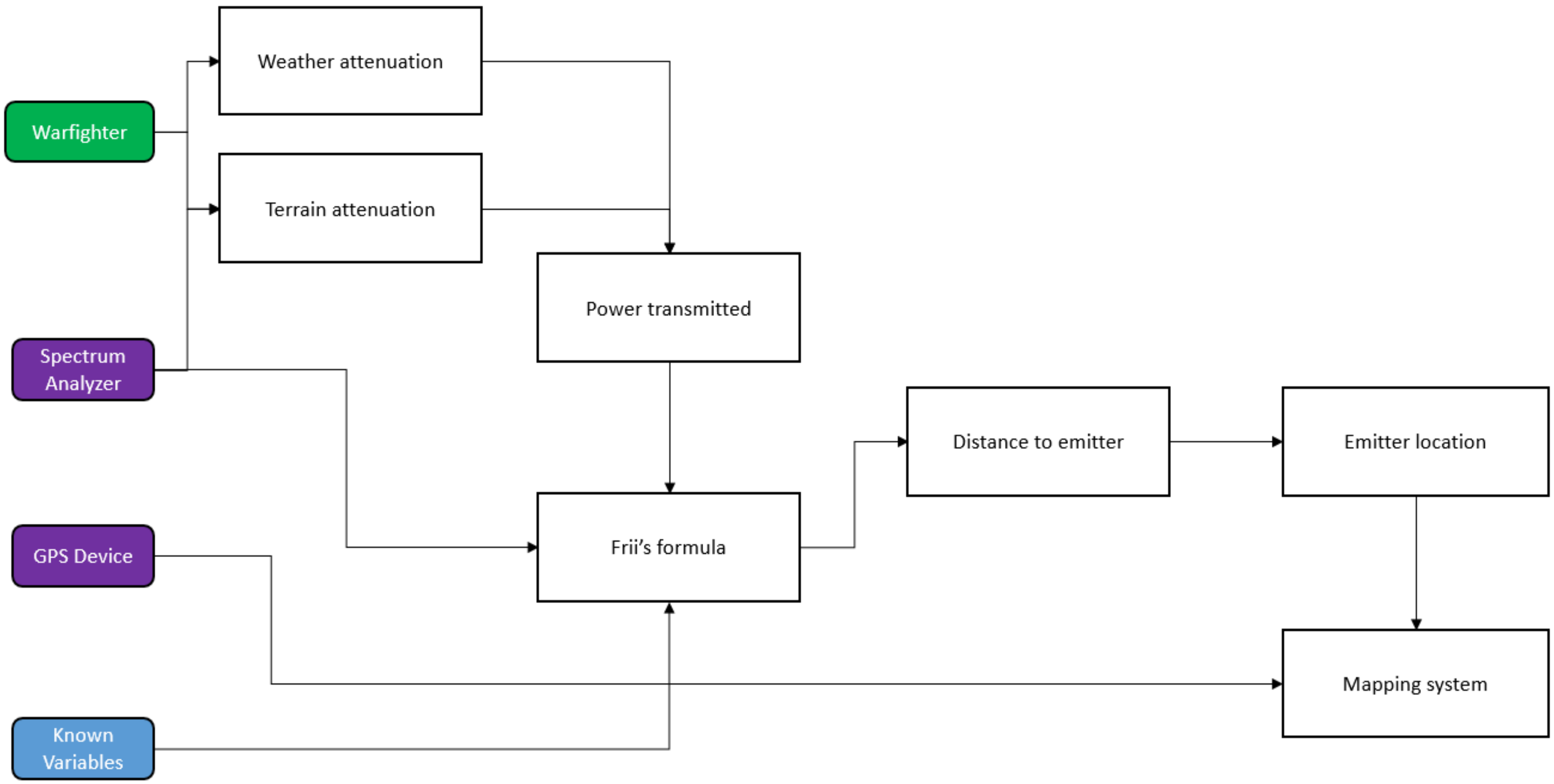


Figure 19. Trace algorithm overview

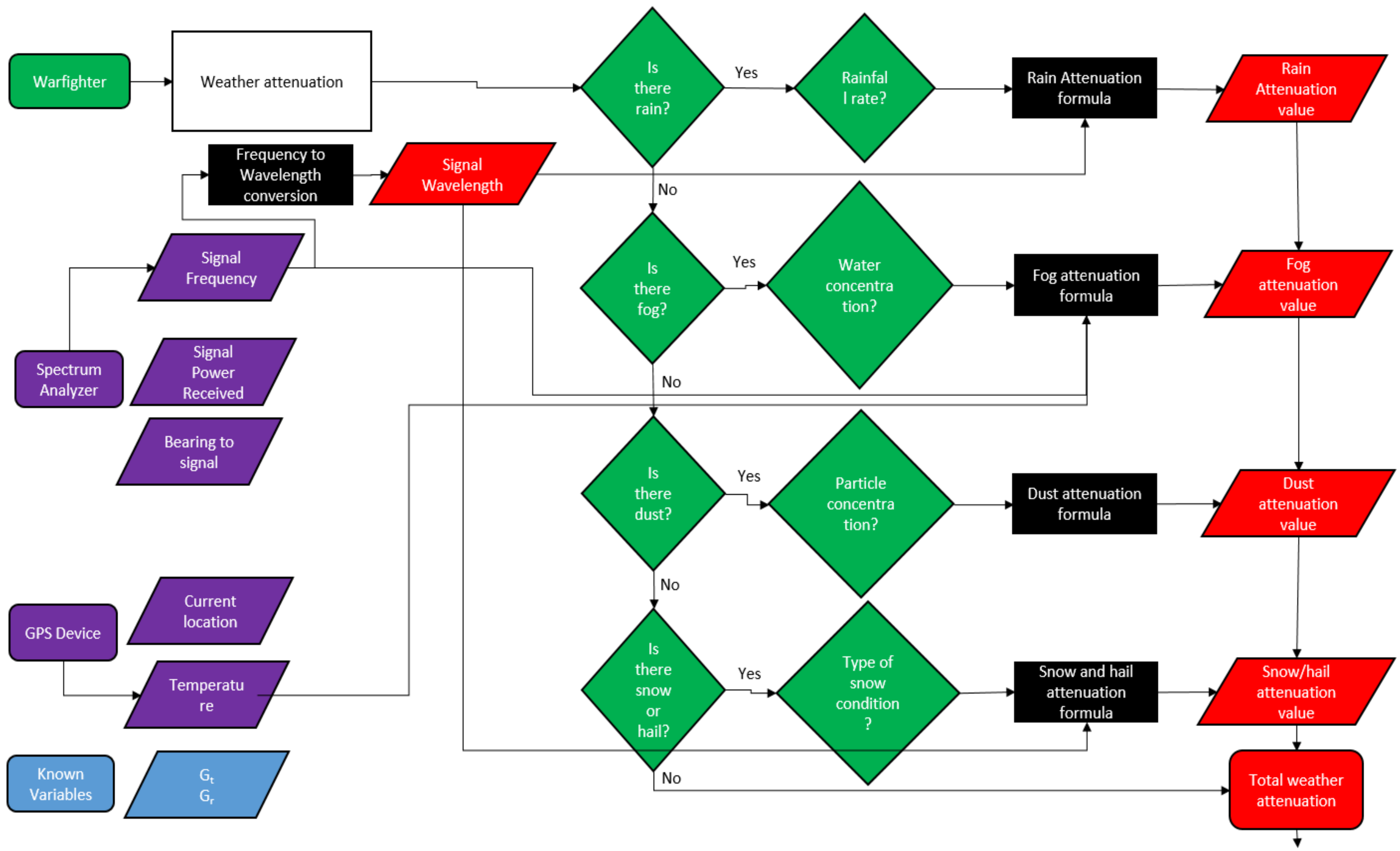


Figure 20. Weather attenuation section of algorithm

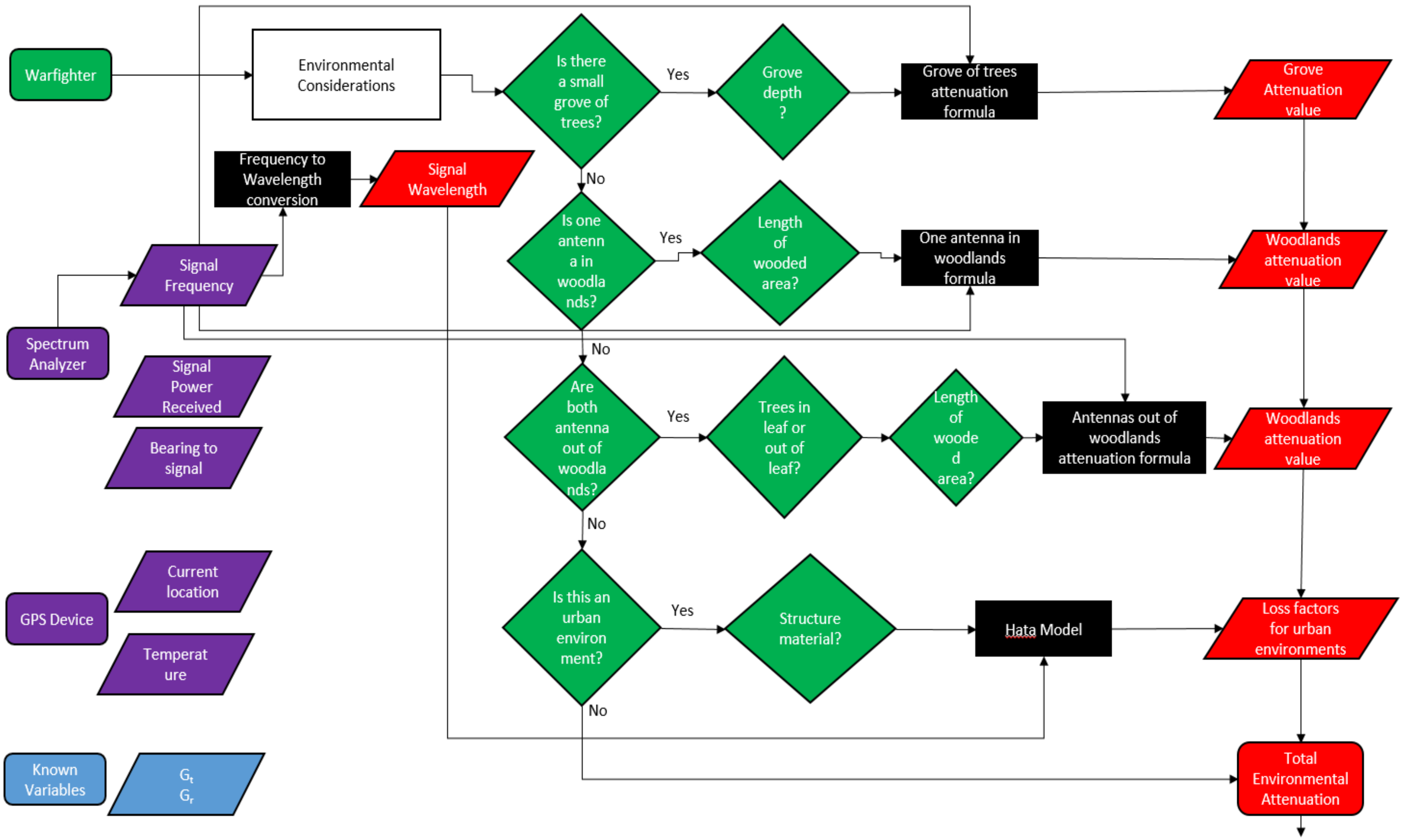


Figure 21. Terrain attenuation section of algorithm

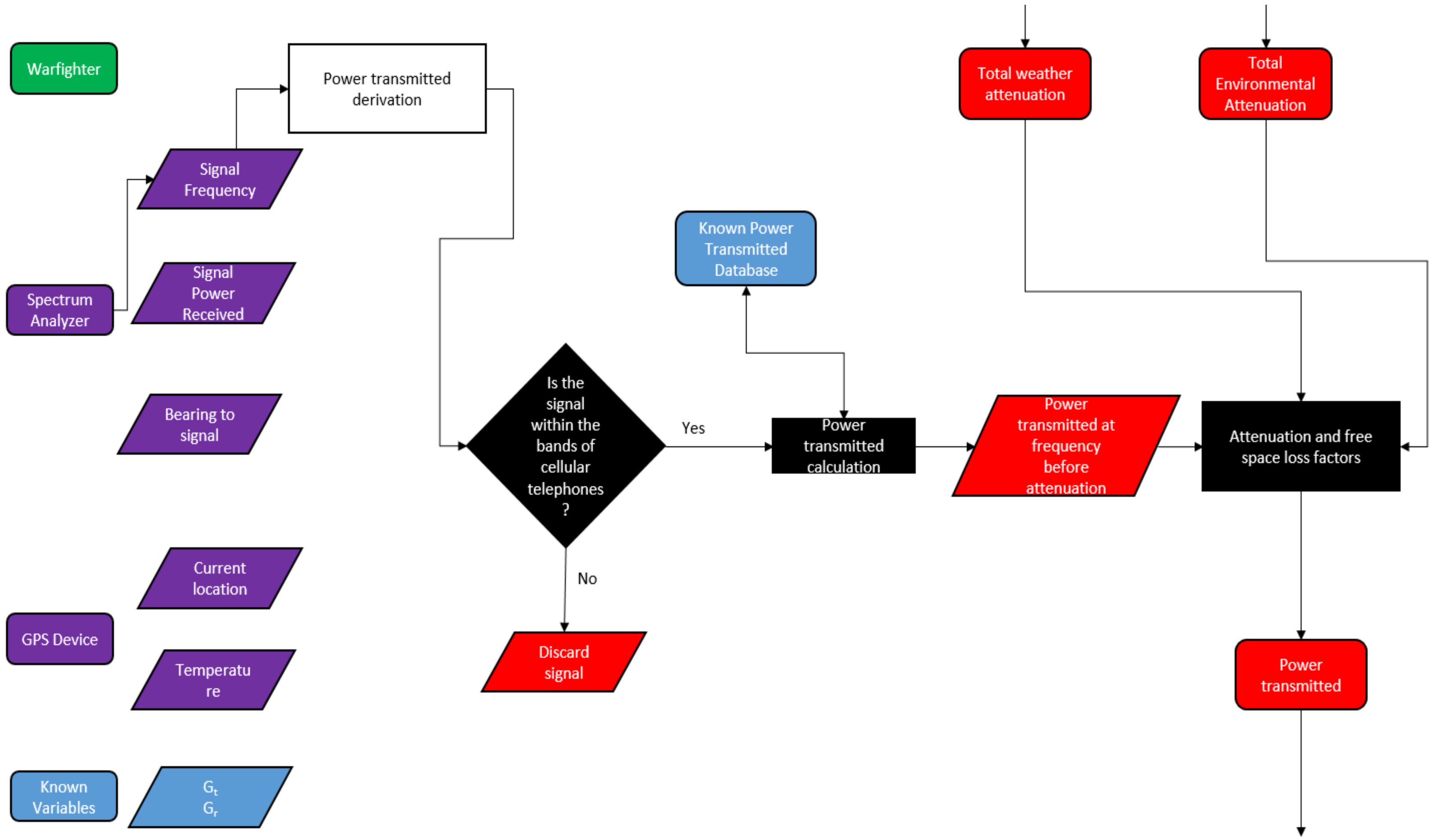


Figure 22. Power transmitted section of algorithm

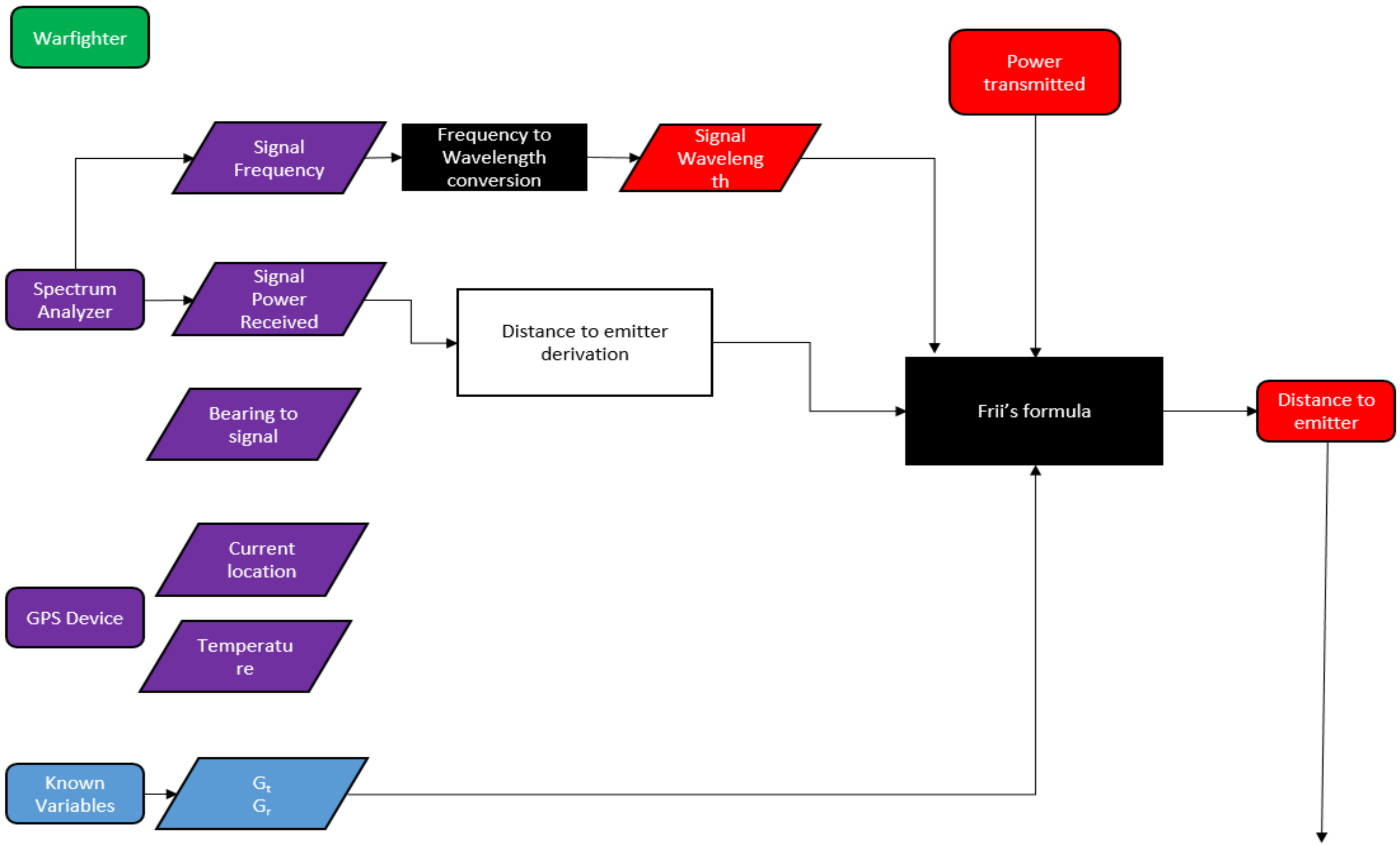


Figure 23. Distance to emitter section of algorithm

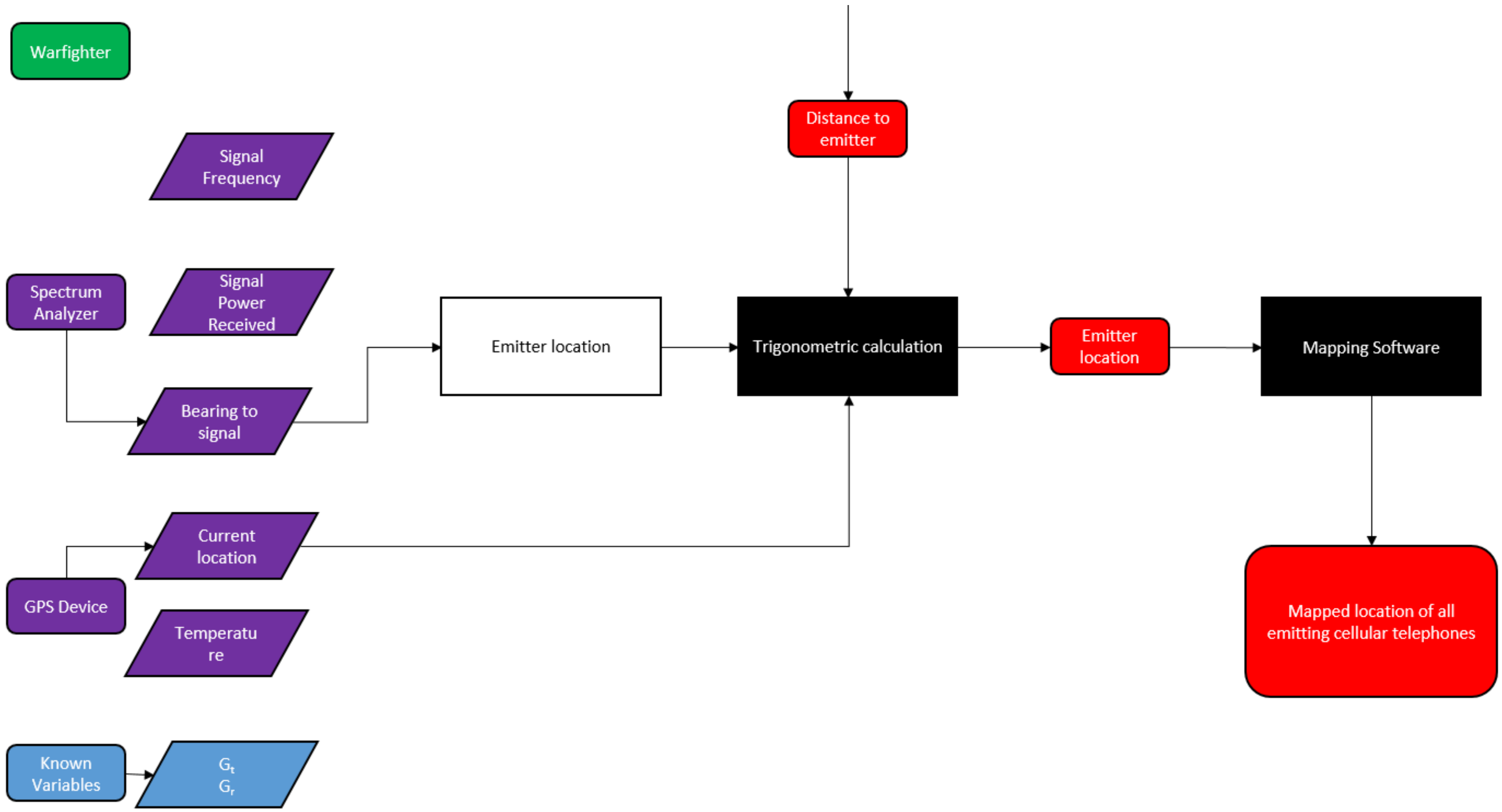


Figure 24. Location mapping and output section of algorithm

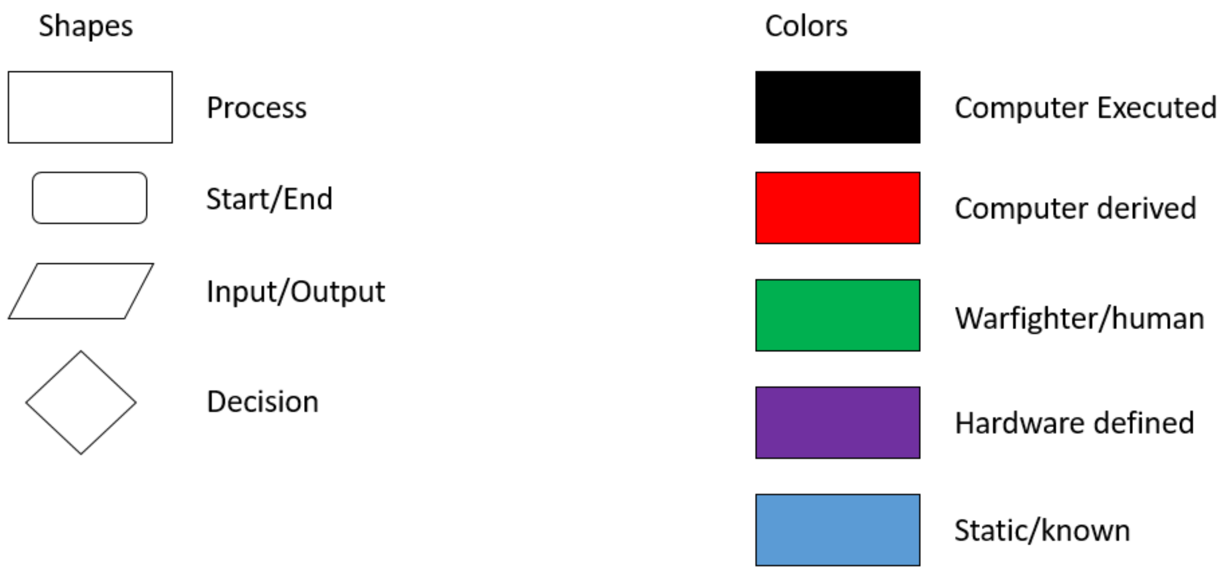


Figure 25. Legend for algorithm understanding

V. CONCLUSION AND RECOMMENDATIONS

A. SUMMARY

Situational awareness is a significant concern to all decision makers on the battlefield. Providing tools to the warfighter that enhance situational awareness can increase the effectiveness of units. Giving a squad the ability to sense the EMS and map the location of cellular telephones could help them defeat RCIEDs. The purpose of this thesis was to develop a means of providing this situational awareness to the warfighter on the battlefield. The current gap in capabilities that create awareness of cellular devices actively transmitting in the local area necessitates ongoing research. This thesis investigated the methodology of coupling existing off-the-shelf technology with a computational algorithm to produce a visual map of all emitting cellular telephones within an area.

By exploiting the mathematical behavior of wave propagation, one can derive tools to increase situational awareness. This thesis shows that a mathematical algorithm can be derived from current wave propagation formulas, open source information gathering and regulatory restrictions to predict the location of emitting cellular devices within a local area. By analyzing current regulations of spectrum allocation, one can gain enough empirical data to accurately approximate the input variables to a mathematical algorithm. Coupling this algorithm with appropriate hardware can provide the warfighter and commander situational awareness of EMS on the battlefield. This study does not derive any new mathematical formulas for wave propagation, but it does present a new means of applying current formulas that would enhance military effectiveness.

B. PROBLEMS

The greatest problem associated with the proposed method of coupling a mathematical algorithm with off-the-shelf technology to provide situational awareness to the warfighter is the current state of off-the-shelf technology. Currently, off-the-shelf handheld technology can only conduct direction finding on a single channel. Possessing the ability to conduct direction finding over multiple channels is currently in the research phase and has not transitioned to production. As seen in this thesis, research into multi-channel direction finding using phased array antennae has been and continues to be conducted, but those findings have yet to be incorporated into off-the-shelf technologies.

C. FUTURE WORK

This thesis laid out the mathematical approach to developing an algorithm to predict the location of specific types of emitters within the EMS. Taking the mathematical approach laid out in this thesis and transitioning it to a computer algorithm would require thorough knowledge of an applicable computing language and a programmer able to execute the coding. Further refining of the process and writing of the code for the algorithm are areas of advancing this research.

Upon the successful coding of the algorithm, testing the accuracy and refining the input parameters in order to increase the accuracy of the range estimation process will be another step in the evolution of this theoretical process. Writing the code and testing the accuracy can be completed without the requirement of a direction finding spectrum analyzer. The mathematical computer algorithm could be later applied to a direction finding device, as that area of technology develops.

Further research should be conducted into the application of SDRs for direction finding. The concept of integrating Mohan et al.'s work (2013) on phase angle analysis with an array of SDRs should be investigated further. As SDRs become prevalent, having a full understanding of how to maximize the utility of these new systems could lead to increased capabilities for our warfighters.

APPENDIX A. FCC FREQUENCY ALLOCATIONS

Appendix A is not a product of the thesis author and is a direct copy of the FCC Online Table of Frequency Allocations. The frequency bands displayed in this sample are for those that cover the operating ranges of cellular telephones. The entire table of allocations is available at https://transition.fcc.gov/oet/spectrum/table/fcctable.pdf.

FEDERAL COMMUNICATIONS COMMISSION OFFICE OF ENGINEERING AND TECHNOLOGY POLICY AND RULES DIVISION

FCC ONLINE TABLE OF FREQUENCY ALLOCATIONS

47 C.F.R. § 2.106

Revised on April 6, 2018

Disclaimer: The Table of Frequency Allocations as published by the Federal Register and codified in the Code of Federal Regulations remains the legal source material. This Online Table of Frequency Allocations may display amendments that have been adopted by the FCC but that have not yet taken effect.

NOTE: If a Rule Part is listed in the last column of the Allocation Table, click here to find those Rules.

Contact Tom Mooring at 202-418-2450 if you have any questions or comments.[1]

[1] The International Table (columns 1-3 of § 2.106) reflects Article 5, Section IV of the ITU *Radio Regulations*, Edition of 2012, except for (a) errors that the ITU has subsequently corrected and (b) the revisions listed below:

Band; Table	Action
2120-2170 MHz; Regions 1 & 3	The bands 2120-2160 and 2160-2170 MHz have been merged.
9.3-9.5 GHz, all Regions	Reference to 5.475 placed to the right of RADIONAVIGATION
24.25-24.45 GHz; Region 3	The services are listed in alphabetical order according to the French language.
International Footnote	Action (The notation "(FCC)" has been added to the end of these footnotes)
5.197A, 5.345, 5.351A, 5.353A, 5.389A, 5.389C, 5.396, 5.444A, 5.516B, 5.547	The cross-references to ITU Resolutions 33, 75, 114, 143, 222, 223, 224, 225, 413, 528, and 716 have been updated to reflect the version listed in the *Radio Regulations*.
5.208B	Note is not shown.

International Table			United States Table		FCC Rule Part(s)
Region 1 Table	Region 2 Table	Region 3 Table	Federal Table	Non-Federal Table	
456-459 FIXED MOBILE 5.286AA 5.271 5.287 5.288			456-459 5.287 US64 US288	456-460 FIXED LAND MOBILE 5.287 US64 US288 NG32 NG112 NG124 NG148	Public Mobile (22) Maritime (80) Private Land Mobile (90) MedRadio (95I)
459-460 FIXED MOBILE 5.286AA 5.209 5.271 5.286A 5.286B 5.286C 5.286E	459-460 FIXED MOBILE 5.286AA MOBILE-SATELLITE (Earth-to-space) 5.286A 5.286B 5.286C 5.209	459-460 FIXED MOBILE 5.286AA 5.209 5.271 5.286A 5.286B 5.286C 5.286E	459-460		
460-470 FIXED MOBILE 5.286AA Meteorological-satellite (space-to-Earth) 5.287 5.288 5.289 5.290			460-470 Meteorological-satellite (space-to-Earth) 5.287 US73 US209 US288 US289	460-462.5375 FIXED LAND MOBILE US209 US289 NG124	Private Land Mobile (90)
				462.5375-462.7375 LAND MOBILE US289	Personal Radio (95)
				462.7375-467.5375 FIXED LAND MOBILE 5.287 US73 US209 US288 US289 NG124	Maritime (80) Private Land Mobile (90)
				467.5375-467.7375 LAND MOBILE 5.287 US288 US289	Maritime (80) Personal Radio (95)
				467.7375-470 FIXED LAND MOBILE US73 US288 US289 NG124	Maritime (80) Private Land Mobile (90)
470-790 BROADCASTING	470-512 BROADCASTING Fixed Mobile 5.292 5.293	470-585 FIXED MOBILE BROADCASTING 5.291 5.298	470-608	470-512 FIXED LAND MOBILE BROADCASTING NG5 NG14 NG66 NG115 NG149	Public Mobile (22) Broadcast Radio (TV)(73) LPTV, TV Translator/Booster (74G) Low Power Auxiliary (74H) Private Land Mobile (90)
	512-608 BROADCASTING 5.297	585-610 FIXED MOBILE BROADCASTING RADIONAVIGATION 5.149 5.305 5.306 5.307		512-608 BROADCASTING NG5 NG14 NG115 NG149	Broadcast Radio (TV)(73) LPTV, TV Translator/Booster (74G) Low Power Auxiliary (74H)
	608-614 RADIO ASTRONOMY Mobile-satellite except aeronautical mobile-satellite (Earth-to-space)	610-890 FIXED MOBILE 5.313A 5.317A BROADCASTING	608-614 LAND MOBILE (medical telemetry and medical telecommand) RADIO ASTRONOMY US74 US246		Personal Radio (95)

	614-698 BROADCASTING Fixed Mobile 5.293 5.309 5.311A		614-698	614-698 FIXED MOBILE NG5 NG14 NG33 NG115 NG149	RF Devices (15) Wireless Communications (27) LPTV, TV Translator/Booster (74G) Low Power Auxiliary (74H)
	698-806 MOBILE 5.313B 5.317A BROADCASTING Fixed		698-758	698-758 FIXED MOBILE BROADCASTING NG159	Wireless Communications (27) LPTV and TV Translator (74G)
			758-775	758-775 FIXED MOBILE NG34 NG159	Public Safety Land Mobile (90R)
5.149 5.291A 5.294 5.296 5.300 5.304 5.306 5.311A 5.312 5.312A			775-788	775-788 FIXED MOBILE BROADCASTING NG159	Wireless Communications (27) LPTV and TV Translator (74G)
790-862 FIXED MOBILE except aeronautical mobile 5.316B 5.317A BROADCASTING			788-805	788-805 FIXED MOBILE NG34 NG159	Public Safety Land Mobile (90R)
	5.293 5.309 5.311A		805-806	805-806 FIXED MOBILE BROADCASTING NG159	Wireless Communications (27) LPTV and TV Translator (74G)
	806-890 FIXED MOBILE 5.317A BROADCASTING		806-809	806-809 LAND MOBILE	Public Safety Land Mobile (90S)
			809-851	809-849 FIXED LAND MOBILE	Public Mobile (22) Private Land Mobile (90)
				849-851 AERONAUTICAL MOBILE	Public Mobile (22)
5.312 5.314 5.315 5.316 5.316A 5.319			851-854	851-854 LAND MOBILE	Public Safety Land Mobile (90S)
862-890 FIXED MOBILE except aeronautical mobile 5.317A BROADCASTING 5.322 5.319 5.323	5.317 5.318	5.149 5.305 5.306 5.307 5.311A 5.320	854-890	854-894 FIXED LAND MOBILE US116 US268	Public Mobile (22) Private Land Mobile (90)

International Table			United States Table		FCC Rule Part(s)
Region 1 Table	Region 2 Table	Region 3 Table	Federal Table	Non-Federal Table	
890-942 FIXED MOBILE except aeronautical mobile 5.317A BROADCASTING 5.322 Radiolocation	890-902 FIXED MOBILE except aeronautical mobile 5.317A Radiolocation 5.318 5.325	890-942 FIXED MOBILE 5.317A BROADCASTING Radiolocation	890-902 US116 US268 G2	(See previous page)	
				894-896 AERONAUTICAL MOBILE US116 US268	Public Mobile (22)
				896-901 FIXED LAND MOBILE US116 US268	Private Land Mobile (90)
				901-902 FIXED MOBILE US116 US268	Personal Communications (24)
	902-928 FIXED Amateur Mobile except aeronautical mobile 5.325A Radiolocation 5.150 5.325 5.326		902-928 RADIOLOCATION G59 5.150 US218 US267 US275 G11	902-928 5.150 US218 US267 US275	ISM Equipment (18) Private Land Mobile (90) Amateur Radio (97)
	928-942 FIXED MOBILE except aeronautical mobile 5.317A Radiolocation		928-932 US116 US268 G2	928-929 FIXED US116 US268 NG35	Public Mobile (22) Private Land Mobile (90) Fixed Microwave (101)
				929-930 FIXED LAND MOBILE US116 US268	Private Land Mobile (90)
				930-931 FIXED MOBILE US116 US268	Personal Communications (24)
				931-932 FIXED LAND MOBILE US116 US268	Public Mobile (22)
			932-935 FIXED US268 G2	932-935 FIXED US268 NG35	Public Mobile (22) Fixed Microwave (101)
			935-941 US116 US268 G2	935-940 FIXED LAND MOBILE US116 US268	Private Land Mobile (90)
				940-941 FIXED MOBILE US116 US268	Personal Communications (24)

Region 1 Table	Region 2 Table	Region 3 Table	Federal Table	Non-Federal Table	FCC Rule Part(s)
5.323	5.325	5.327	941-944 FIXED US84 US268 US301 G2	941-944 FIXED US84 US268 US301 NG30 NG35	Public Mobile (22) Aural Broadcast Auxiliary (74E) Low Power Auxiliary (74H) Fixed Microwave (101)
942-960 FIXED MOBILE except aeronautical mobile 5.317A BROADCASTING 5.322 5.323	942-960 FIXED MOBILE 5.317A	942-960 FIXED MOBILE 5.317A BROADCASTING 5.320	944-960	944-960 FIXED NG35	
960-1164 AERONAUTICAL MOBILE (R) 5.327A AERONAUTICAL RADIONAVIGATION 5.328			960-1164 AERONAUTICAL MOBILE (R) 5.327A AERONAUTICAL RADIONAVIGATION 5.328 US224		Aviation (87)
1164-1215 AERONAUTICAL RADIONAVIGATION 5.328 RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space) 5.328B 5.328A			1164-1215 AERONAUTICAL RADIONAVIGATION 5.328 RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space) 5.328A US224		
1215-1240 EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space) 5.328B 5.329 5.329A SPACE RESEARCH (active) 5.330 5.331 5.332			1215-1240 EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION G56 RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space) G132 SPACE RESEARCH (active) 5.332	1215-1240 Earth exploration-satellite (active) Space research (active)	
1240-1300 EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space) 5.328B 5.329 5.329A SPACE RESEARCH (active) Amateur 5.282 5.330 5.331 5.332 5.335 5.335A			1240-1300 EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION G56 SPACE RESEARCH (active) AERONAUTICAL RADIONAVIGATION 5.332 5.335	1240-1300 AERONAUTICAL RADIONAVIGATION Amateur Earth exploration-satellite (active) Space research (active) 5.282	Amateur Radio (97)
1300-1350 RADIOLOCATION AERONAUTICAL RADIONAVIGATION 5.337 RADIONAVIGATION-SATELLITE (Earth-to-space) 5.149 5.337A			1300-1350 AERONAUTICAL RADIONAVIGATION 5.337 Radiolocation G2 US342	1300-1350 AERONAUTICAL RADIONAVIGATION 5.337 US342	Aviation (87)
1350-1400 FIXED MOBILE RADIOLOCATION 5.149 5.338 5.338A 5.339	1350-1400 RADIOLOCATION 5.338A 5.149 5.334 5.339		1350-1390 FIXED MOBILE RADIOLOCATION G2 5.334 5.339 US342 US385 G27 G114	1350-1390 5.334 5.339 US342 US385	
			1390-1395 5.339 US79 US342 US385	1390-1395 FIXED MOBILE except aeronautical mobile 5.339 US79 US342 US385 NG338A	Wireless Communications (27)
			1395-1400 LAND MOBILE (medical telemetry and medical telecommand) 5.339 US79 US342 US385		Personal Radio (95)

International Table			United States Table		FCC Rule Part(s)
Region 1 Table	Region 2 Table	Region 3 Table	Federal Table	Non-Federal Table	
1400-1427 EARTH EXPLORATION-SATELLITE (passive) RADIO ASTRONOMY SPACE RESEARCH (passive) 5.340 5.341			1400-1427 EARTH EXPLORATION-SATELLITE (passive) RADIO ASTRONOMY US74 SPACE RESEARCH (passive) 5.341 US246		
1427-1429 SPACE OPERATION (Earth-to-space) FIXED MOBILE except aeronautical mobile 5.338A 5.341			1427-1429.5 LAND MOBILE (medical telemetry and medical telecommand) US350 5.341 US79	1427-1429.5 LAND MOBILE (telemetry and telecommand) Fixed (telemetry) 5.341 US79 US350 NG338A	Private Land Mobile (90) Personal Radio (95)
1429-1452 FIXED MOBILE except aeronautical mobile 5.338A 5.341 5.342	1429-1452 FIXED MOBILE 5.343 5.338A 5.341		1429.5-1432 5.341 US79 US350	1429.5-1432 FIXED (telemetry and telecommand) LAND MOBILE (telemetry and telecommand) 5.341 US79 US350 NG338A	
			1432-1435 5.341 US83	1432-1435 FIXED MOBILE except aeronautical mobile 5.341 US83 NG338A	Wireless Communications (27)
1452-1492 FIXED MOBILE except aeronautical mobile BROADCASTING BROADCASTING-SATELLITE 5.208B 5.341 5.342 5.345	1452-1492 FIXED MOBILE 5.343 BROADCASTING BROADCASTING-SATELLITE 5.208B 5.341 5.344 5.345		1435-1525 MOBILE (aeronautical telemetry) US338A		Aviation (87)
1492-1518 FIXED MOBILE except aeronautical mobile 5.341 5.342	1492-1518 FIXED MOBILE 5.343 5.341 5.344	1492-1518 FIXED MOBILE 5.341			
1518-1525 FIXED MOBILE except aeronautical mobile MOBILE-SATELLITE (space-to-Earth) 5.348 5.348A 5.348B 5.351A 5.341 5.342	1518-1525 FIXED MOBILE 5.343 MOBILE-SATELLITE (space-to-Earth) 5.348 5.348A 5.348B 5.351A 5.341 5.344	1518-1525 FIXED MOBILE MOBILE-SATELLITE (space-to-Earth) 5.348 5.348A 5.348B 5.351A 5.341	5.341 US84 US343		

1525-1530 SPACE OPERATION (space-to-Earth) FIXED MOBILE-SATELLITE (space-to-Earth) 5.208B 5.351A Earth exploration-satellite Mobile except aeronautical mobile 5.349 5.341 5.342 5.350 5.351 5.352A 5.354	1525-1530 SPACE OPERATION (space-to-Earth) MOBILE-SATELLITE (space-to-Earth) 5.208B 5.351A Earth exploration-satellite Fixed Mobile 5.343 5.341 5.351 5.354	1525-1530 SPACE OPERATION (space-to-Earth) FIXED MOBILE-SATELLITE (space-to-Earth) 5.208B 5.351A Earth exploration-satellite Mobile 5.349 5.341 5.351 5.352A 5.354	1525-1535 MOBILE-SATELLITE (space-to-Earth) US315 US380 5.341 5.351	Satellite Communications (25) Maritime (80)
1530-1535 SPACE OPERATION (space-to-Earth) MOBILE-SATELLITE (space-to-Earth) 5.208B 5.351A 5.353A Earth exploration-satellite Fixed Mobile except aeronautical mobile 5.341 5.342 5.351 5.354	1530-1535 SPACE OPERATION (space-to-Earth) MOBILE-SATELLITE (space-to-Earth) 5.208B 5.351A 5.353A Earth exploration-satellite Fixed Mobile 5.343 5.341 5.351 5.354			
1535-1559 MOBILE-SATELLITE (space-to-Earth) 5.208B 5.351A 5.341 5.351 5.353A 5.354 5.355 5.356 5.357 5.357A 5.359 5.362A			1535-1559 MOBILE-SATELLITE (space-to-Earth) US308 US309 US315 US380 5.341 5.351 5.356	Satellite Communications (25) Maritime (80) Aviation (87)
1559-1610 AERONAUTICAL RADIONAVIGATION RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space) 5.208B 5.328B 5.329A 5.341 5.362B 5.362C			1559-1610 AERONAUTICAL RADIONAVIGATION RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space) 5.341 US85 US208 US260	Aviation (87)
1610-1610.6 MOBILE-SATELLITE (Earth-to-space) 5.351A AERONAUTICAL RADIONAVIGATION 5.341 5.355 5.359 5.364 5.366 5.367 5.368 5.369 5.371 5.372	1610-1610.6 MOBILE-SATELLITE (Earth-to-space) 5.351A AERONAUTICAL RADIONAVIGATION RADIODETERMINATION-SATELLITE (Earth-to-space) 5.341 5.364 5.366 5.367 5.368 5.370 5.372	1610-1610.6 MOBILE-SATELLITE (Earth-to-space) 5.351A AERONAUTICAL RADIONAVIGATION Radiodetermination-satellite (Earth-to-space) 5.341 5.355 5.359 5.364 5.366 5.367 5.368 5.369 5.372	1610-1610.6 MOBILE-SATELLITE (Earth-to-space) US319 US380 AERONAUTICAL RADIONAVIGATION US260 RADIODETERMINATION-SATELLITE (Earth-to-space) 5.341 5.364 5.366 5.367 5.368 5.372 US208	Satellite Communications (25) Aviation (87)
1610.6-1613.8 MOBILE-SATELLITE (Earth-to-space) 5.351A RADIO ASTRONOMY AERONAUTICAL RADIONAVIGATION 5.149 5.341 5.355 5.359 5.364 5.366 5.367 5.368 5.369 5.371 5.372	1610.6-1613.8 MOBILE-SATELLITE (Earth-to-space) 5.351A RADIO ASTRONOMY AERONAUTICAL RADIONAVIGATION RADIODETERMINATION-SATELLITE (Earth-to-space) 5.149 5.341 5.364 5.366 5.367 5.368 5.370 5.372	1610.6-1613.8 MOBILE-SATELLITE (Earth-to-space) 5.351A RADIO ASTRONOMY AERONAUTICAL RADIONAVIGATION Radiodetermination-satellite (Earth-to-space) 5.149 5.341 5.355 5.359 5.364 5.366 5.367 5.368 5.369 5.372	1610.6-1613.8 MOBILE-SATELLITE (Earth-to-space) US319 US380 RADIO ASTRONOMY AERONAUTICAL RADIONAVIGATION US260 RADIODETERMINATION-SATELLITE (Earth-to-space) 5.341 5.364 5.366 5.367 5.368 5.372 US208 US342	
1613.8-1626.5 MOBILE-SATELLITE (Earth-to-space) 5.351A AERONAUTICAL RADIONAVIGATION Mobile-satellite (space-to-Earth) 5.208B 5.341 5.355 5.359 5.364 5.365 5.366 5.367 5.368 5.369 5.371 5.372	1613.8-1626.5 MOBILE-SATELLITE (Earth-to-space) 5.351A AERONAUTICAL RADIONAVIGATION RADIODETERMINATION-SATELLITE (Earth-to-space) Mobile-satellite (space-to-Earth) 5.208B 5.341 5.364 5.365 5.366 5.367 5.368 5.370 5.372	1613.8-1626.5 MOBILE-SATELLITE (Earth-to-space) 5.351A AERONAUTICAL RADIONAVIGATION Mobile-satellite (space-to-Earth) 5.208B Radiodetermination-satellite (Earth-to-space) 5.341 5.355 5.359 5.364 5.365 5.366 5.367 5.368 5.369 5.372	1613.8-1626.5 MOBILE-SATELLITE (Earth-to-space) US319 US380 AERONAUTICAL RADIONAVIGATION US260 RADIODETERMINATION-SATELLITE (Earth-to-space) Mobile-satellite (space-to-Earth) 5.341 5.364 5.365 5.366 5.367 5.368 5.372 US208	

International Table			United States Table		FCC Rule Part(s)
Region 1 Table	Region 2 Table	Region 3 Table	Federal Table	Non-Federal Table	
1626.5-1660 MOBILE-SATELLITE (Earth-to-space) 5.351A 5.341 5.351 5.353A 5.354 5.355 5.357A 5.359 5.362A 5.374 5.375 5.376			1626.5-1660 MOBILE-SATELLITE (Earth-to-space) US308 US309 US315 US380 5.341 5.351 5.375		Satellite Communications (25) Maritime (80) Aviation (87)
1660-1660.5 MOBILE-SATELLITE (Earth-to-space) 5.351A RADIO ASTRONOMY 5.149 5.341 5.351 5.354 5.362A 5.376A			1660-1660.5 MOBILE-SATELLITE (Earth-to-space) US308 US309 US380 RADIO ASTRONOMY 5.341 5.351 US342		Satellite Communications (25) Aviation (87)
1660.5-1668 RADIO ASTRONOMY SPACE RESEARCH (passive) Fixed Mobile except aeronautical mobile 5.149 5.341 5.379 5.379A			1660.5-1668.4 RADIO ASTRONOMY US74 SPACE RESEARCH (passive) 5.341 US246		
1668-1668.4 MOBILE-SATELLITE (Earth-to-space) 5.351A 5.379B 5.379C RADIO ASTRONOMY SPACE RESEARCH (passive) Fixed Mobile except aeronautical mobile 5.149 5.341 5.379 5.379A					
1668.4-1670 METEOROLOGICAL AIDS FIXED MOBILE except aeronautical mobile MOBILE-SATELLITE (Earth-to-space) 5.351A 5.379B 5.379C RADIO ASTRONOMY 5.149 5.341 5.379D 5.379E			1668.4-1670 METEOROLOGICAL AIDS (radiosonde) RADIO ASTRONOMY US74 5.341 US99 US342		
1670-1675 METEOROLOGICAL AIDS FIXED METEOROLOGICAL-SATELLITE (space-to-Earth) MOBILE MOBILE-SATELLITE (Earth-to-space) 5.351A 5.379B 5.341 5.379D 5.379E 5.380A			1670-1675 5.341 US211 US362	1670-1675 FIXED MOBILE except aeronautical mobile 5.341 US211 US362	Wireless Communications (27)
1675-1690 METEOROLOGICAL AIDS FIXED METEOROLOGICAL-SATELLITE (space-to-Earth) MOBILE except aeronautical mobile 5.341			1675-1695 METEOROLOGICAL AIDS (radiosonde) METEOROLOGICAL-SATELLITE (space-to-Earth) US88 5.341 US211 US289		

1690-1700 METEOROLOGICAL AIDS METEOROLOGICAL-SATELLITE (space-to-Earth) Fixed Mobile except aeronautical mobile	1690-1700 METEOROLOGICAL AIDS METEOROLOGICAL-SATELLITE (space-to-Earth)	1695-1710 METEOROLOGICAL-SATELLITE (space-to-Earth) US88	1695-1710 FIXED MOBILE except aeronautical mobile	Wireless Communications (27)

1700-1710 FIXED METEOROLOGICAL-SATELLITE (space-to-Earth) MOBILE except aeronautical mobile 5.289 5.341		1700-1710 FIXED METEOROLOGICAL-SATELLITE (space-to-Earth) MOBILE except aeronautical mobile 5.289 5.341 5.384	5.341	5.341 US88	
1710-1930 FIXED MOBILE 5.384A 5.388A 5.388B 5.149 5.341 5.385 5.386 5.387 5.388			1710-1761 5.341 US91 US378 US385	1710-1780 FIXED MOBILE 5.341 US91 US378 US385	
			1761-1780 SPACE OPERATION (Earth-to-space) G42 US91		
			1780-1850 FIXED MOBILE SPACE OPERATION (Earth-to-space) G42	1780-1850	
1930-1970 FIXED MOBILE 5.388A 5.388B 5.388	1930-1970 FIXED MOBILE 5.388A 5.388B Mobile-satellite (Earth-to-space) 5.388	1930-1970 FIXED MOBILE 5.388A 5.388B 5.388	1850-2025	1850-2000 FIXED MOBILE	RF Devices (15) Personal Communications (24) Wireless Communications (27) Fixed Microwave (101)
1970-1980 FIXED MOBILE 5.388A 5.388B 5.388					
1980-2010 FIXED MOBILE MOBILE-SATELLITE (Earth-to-space) 5.351A 5.388 5.389A 5.389B 5.389F					
				2000-2020 FIXED MOBILE MOBILE-SATELLITE (Earth-to-space)	Satellite Communications (25) Wireless Communications (27)
2010-2025 FIXED MOBILE 5.388A 5.388B 5.388	2010-2025 FIXED MOBILE MOBILE-SATELLITE (Earth-to-space) 5.388 5.389C 5.389E	2010-2025 FIXED MOBILE 5.388A 5.388B 5.388		2020-2025 FIXED MOBILE	
2025-2110 SPACE OPERATION (Earth-to-space) (space-to-space) EARTH EXPLORATION-SATELLITE (Earth-to-space) (space-to-space) FIXED MOBILE 5.391 SPACE RESEARCH (Earth-to-space) (space-to-space) 5.392			2025-2110 SPACE OPERATION (Earth-to-space) (space-to-space) EARTH EXPLORATION-SATELLITE (Earth-to-space) (space-to-space) SPACE RESEARCH (Earth-to-space) (space-to-space) FIXED MOBILE 5.391 5.392 US90 US92 US222 US346 US347	2025-2110 FIXED NG118 MOBILE 5.391 5.392 US90 US92 US222 US346 US347	TV Auxiliary Broadcasting (74F) Cable TV Relay (78) Local TV Transmission (101J)

International Table			United States Table		FCC Rule Part(s)
Region 1 Table	Region 2 Table	Region 3 Table	Federal Table	Non-Federal Table	
2110-2120 FIXED MOBILE 5.388A 5.388B SPACE RESEARCH (deep space) (Earth-to-space) 5.388			2110-2120 US252	2110-2120 FIXED MOBILE US252	Public Mobile (22) Wireless Communications (27) Fixed Microwave (101)
2120-2170 FIXED MOBILE 5.388A 5.388B 5.388	2120-2160 FIXED MOBILE 5.388A 5.388B Mobile-satellite (space-to-Earth) 5.388	2120-2170 FIXED MOBILE 5.388A 5.388B 5.388	2120-2200	2120-2180 FIXED MOBILE NG41	
	2160-2170 FIXED MOBILE MOBILE-SATELLITE (space-to-Earth) 5.388 5.389C 5.389E				
2170-2200 FIXED MOBILE MOBILE-SATELLITE (space-to-Earth) 5.351A 5.388 5.389A 5.389F				2180-2200 FIXED MOBILE MOBILE-SATELLITE (space-to-Earth)	Satellite Communications (25) Wireless Communications (27)
2200-2290 SPACE OPERATION (space-to-Earth) (space-to-space) EARTH EXPLORATION-SATELLITE (space-to-Earth) (space-to-space) FIXED MOBILE 5.391 SPACE RESEARCH (space-to-Earth) (space-to-space) 5.392			2200-2290 SPACE OPERATION (space-to-Earth) (space-to-space) EARTH EXPLORATION-SATELLITE (space-to-Earth) (space-to-space) FIXED (line-of-sight only) MOBILE (line-of-sight only including aeronautical telemetry, but excluding flight testing of manned aircraft) 5.391 SPACE RESEARCH (space-to-Earth) (space-to-space) 5.392 US303	2200-2290 US303	
2290-2300 FIXED MOBILE except aeronautical mobile SPACE RESEARCH (deep space) (space-to-Earth)			2290-2300 FIXED MOBILE except aeronautical mobile SPACE RESEARCH (deep space) (space-to-Earth)	2290-2300 SPACE RESEARCH (deep space) (space-to-Earth)	
2300-2450 FIXED MOBILE 5.384A Amateur Radiolocation	2300-2450 FIXED MOBILE 5.384A RADIOLOCATION Amateur		2300-2305 G122	2300-2305 Amateur	Amateur Radio (97)
			2305-2310 US97 G122	2305-2310 FIXED MOBILE except aeronautical mobile RADIOLOCATION Amateur US97	Wireless Communications (27) Amateur Radio (97)

		2310-2320 Fixed Mobile US100 Radiolocation G2 US97 US327	2310-2320 FIXED MOBILE BROADCASTING-SATELLITE RADIOLOCATION 5.396 US97 US100 US327	Wireless Communications (27)
		2320-2345 Fixed Radiolocation G2 US327	2320-2345 BROADCASTING-SATELLITE 5.396 US327	Satellite Communications (25)
		2345-2360 Fixed Mobile US100 Radiolocation G2 US327	2345-2360 FIXED MOBILE US100 BROADCASTING-SATELLITE RADIOLOCATION 5.396 US327	Wireless Communications (27)
		2360-2390 MOBILE US276 RADIOLOCATION G2 G120 Fixed US101	2360-2390 MOBILE US276 US101	Aviation (87) Personal Radio (95)
		2390-2395 MOBILE US276 US101	2390-2395 AMATEUR MOBILE US276 US101	Aviation (87) Personal Radio (95) Amateur Radio (97)
		2395-2400 US101 G122	2395-2400 AMATEUR US101	Personal Radio (95) Amateur Radio (97)
		2400-2417 5.150 G122	2400-2417 AMATEUR 5.150 5.282	ISM Equipment (18) Amateur Radio (97)
5.150 5.282 5.395	5.150 5.282 5.393 5.394 5.396	2417-2450 Radiolocation G2 5.150	2417-2450 Amateur 5.150 5.282	
2450-2483.5 FIXED MOBILE Radiolocation 5.150	2450-2483.5 FIXED MOBILE RADIOLOCATION 5.150	2450-2483.5 5.150 US41	2450-2483.5 FIXED MOBILE Radiolocation 5.150 US41	ISM Equipment (18) TV Auxiliary Broadcasting (74F) Private Land Mobile (90) Fixed Microwave (101)

International Table			United States Table		FCC Rule Part(s)
Region 1 Table	Region 2 Table	Region 3 Table	Federal Table	Non-Federal Table	
2483.5-2500 FIXED MOBILE MOBILE-SATELLITE (space-to-Earth) 5.351A RADIODETERMINATION-SATELLITE (space-to-Earth) 5.398 Radiolocation 5.398A 5.150 5.399 5.401 5.402	2483.5-2500 FIXED MOBILE MOBILE-SATELLITE (space-to-Earth) 5.351A RADIOLOCATION RADIODETERMINATION-SATELLITE (space-to-Earth) 5.398 5.150 5.402	2483.5-2500 FIXED MOBILE MOBILE-SATELLITE (space-to-Earth) 5.351A RADIOLOCATION RADIODETERMINATION-SATELLITE (space-to-Earth) 5.398 5.150 5.401 5.402	2483.5-2500 MOBILE-SATELLITE (space-to-Earth) US319 US380 US391 RADIODETERMINATION-SATELLITE (space-to-Earth) 5.398 5.150 5.402 US41	2483.5-2495 MOBILE-SATELLITE (space-to-Earth) US380 RADIODETERMINATION-SATELLITE (space-to-Earth) 5.398 5.150 5.402 US41 US319 NG147 2495-2500 FIXED MOBILE except aeronautical mobile MOBILE-SATELLITE (space-to-Earth) US380 RADIODETERMINATION-SATELLITE (space-to-Earth) 5.398 5.150 5.402 US41 US319 US391 NG147	ISM Equipment (18) Satellite Communications (25) ISM Equipment (18) Satellite Communications (25) Wireless Communications (27)
2500-2520 FIXED 5.410 MOBILE except aeronautical mobile 5.384A 5.412	2500-2520 FIXED 5.410 FIXED-SATELLITE (space-to-Earth) 5.415 MOBILE except aeronautical mobile 5.384A 5.404	2500-2520 FIXED 5.410 FIXED-SATELLITE (space-to-Earth) 5.415 MOBILE except aeronautical mobile 5.384A MOBILE-SATELLITE (space-to-Earth) 5.351A 5.407 5.414 5.414A 5.404 5.415A	2500-2655 5.339 US205	2500-2655 FIXED US205 MOBILE except aeronautical mobile 5.339	Wireless Communications (27)
2520-2655 FIXED 5.410 MOBILE except aeronautical mobile 5.384A BROADCASTING-SATELLITE 5.413 5.416 5.339 5.412 5.417C 5.417D 5.418B 5.418C	2520-2655 FIXED 5.410 FIXED-SATELLITE (space-to-Earth) 5.415 MOBILE except aeronautical mobile 5.384A BROADCASTING-SATELLITE 5.413 5.416 5.339 5.417C 5.417D 5.418B 5.418C	2520-2535 FIXED 5.410 FIXED-SATELLITE (space-to-Earth) 5.415 MOBILE except aeronautical mobile 5.384A BROADCASTING-SATELLITE 5.413 5.416 5.403 5.414A 5.415A 2535-2655 FIXED 5.410 MOBILE except aeronautical mobile 5.384A BROADCASTING-SATELLITE 5.413 5.416 5.339 5.417A 5.417B 5.417C 5.417D 5.418 5.418A 5.418B 5.418C			
2655-2670 FIXED 5.410 MOBILE except aeronautical mobile 5.384A BROADCASTING-SATELLITE 5.208B 5.413 5.416 Earth exploration-satellite (passive) Radio astronomy Space research (passive) 5.149 5.412	2655-2670 FIXED 5.410 FIXED-SATELLITE (Earth-to-space) (space-to-Earth) 5.415 MOBILE except aeronautical mobile 5.384A BROADCASTING-SATELLITE 5.413 5.416 Earth exploration-satellite (passive) Radio astronomy Space research (passive) 5.149 5.208B	2655-2670 FIXED 5.410 FIXED-SATELLITE (Earth-to-space) 5.415 MOBILE except aeronautical mobile 5.384A BROADCASTING-SATELLITE 5.413 5.416 Earth exploration-satellite (passive) Radio astronomy Space research (passive) 5.149 5.208B 5.420	2655-2690 Earth exploration-satellite (passive) Radio astronomy US385 Space research (passive)	2655-2690 FIXED US205 MOBILE except aeronautical mobile Earth exploration-satellite (passive) Radio astronomy Space research (passive)	

2670-2690 FIXED 5.410 MOBILE except aeronautical mobile 5.384A Earth exploration-satellite (passive) Radio astronomy Space research (passive) 5.149 5.412	2670-2690 FIXED 5.410 FIXED-SATELLITE (Earth-to-space) (space-to-Earth) 5.208B 5.415 MOBILE except aeronautical mobile 5.384A Earth exploration-satellite (passive) Radio astronomy Space research (passive) 5.149	2670-2690 FIXED 5.410 FIXED-SATELLITE (Earth-to-space) 5.415 MOBILE except aeronautical mobile 5.384A MOBILE-SATELLITE (Earth-to-space) 5.351A 5.419 Earth exploration-satellite (passive) Radio astronomy Space research (passive) 5.149	US205	US385	
2690-2700 EARTH EXPLORATION-SATELLITE (passive) RADIO ASTRONOMY SPACE RESEARCH (passive) 5.340 5.422			2690-2700 EARTH EXPLORATION-SATELLITE (passive) RADIO ASTRONOMY US74 SPACE RESEARCH (passive) US246		
2700-2900 AERONAUTICAL RADIONAVIGATION 5.337 Radiolocation 5.423 5.424			2700-2900 METEOROLOGICAL AIDS AERONAUTICAL RADIONAVIGATION 5.337 US18 Radiolocation G2 5.423 G15	2700-2900 5.423 US18	Aviation (87)
2900-3100 RADIOLOCATION 5.424A RADIONAVIGATION 5.426 5.425 5.427			2900-3100 RADIOLOCATION 5.424A G56 MARITIME RADIONAVIGATION 5.427 US44 US316	2900-3100 MARITIME RADIONAVIGATION Radiolocation US44 5.427 US316	Maritime (80) Private Land Mobile (90)
3100-3300 RADIOLOCATION Earth exploration-satellite (active) Space research (active) 5.149 5.428			3100-3300 RADIOLOCATION G59 Earth exploration-satellite (active) Space research (active) US342	3100-3300 Earth exploration-satellite (active) Space research (active) Radiolocation US342	Private Land Mobile (90)
3300-3400 RADIOLOCATION 5.149 5.429 5.430	3300-3400 RADIOLOCATION Amateur Fixed Mobile 5.149	3300-3400 RADIOLOCATION Amateur 5.149 5.429	3300-3500 RADIOLOCATION US108 G2 US342	3300-3500 Amateur Radiolocation US108 5.282 US342	Private Land Mobile (90) Amateur Radio (97)
3400-3600 FIXED FIXED-SATELLITE (space-to-Earth) Mobile 5.430A Radiolocation 5.431	3400-3500 FIXED FIXED-SATELLITE (space-to-Earth) Amateur Mobile 5.431A Radiolocation 5.433 5.282	3400-3500 FIXED FIXED-SATELLITE (space-to-Earth) Amateur Mobile 5.432 5.432B Radiolocation 5.433 5.282 5.432A			

<table>
<tr><th colspan="3">International Table</th><th colspan="2">United States Table</th><th rowspan="2">FCC Rule Part(s)</th></tr>
<tr><th>Region 1 Table</th><th>Region 2 Table</th><th>Region 3 Table</th><th>Federal Table</th><th>Non-Federal Table</th></tr>
<tr><td rowspan="2">(See previous page)</td><td rowspan="4">3500-3700
FIXED
FIXED-SATELLITE (space-to-Earth)
MOBILE except aeronautical mobile
Radiolocation 5.433</td><td rowspan="2">3500-3600
FIXED
FIXED-SATELLITE (space-to-Earth)
MOBILE except aeronautical mobile 5.433A
Radiolocation 5.433</td><td>3500-3550
RADIOLOCATION G59
AERONAUTICAL RADIONAVIGATION (ground-based) G110</td><td>3500-3550
Radiolocation</td><td>Private Land Mobile (90)</td></tr>
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RADIOLOCATION G59
AERONAUTICAL RADIONAVIGATION (ground-based) G110

US105 US107 US245 US433</td><td>3550-3600
FIXED
MOBILE except aeronautical mobile

US105 US433</td><td>Citizens Broadband (96)</td></tr>
<tr><td rowspan="3">3600-4200
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FIXED-SATELLITE (space-to-Earth)
Mobile</td><td rowspan="2">3600-3700
FIXED
FIXED-SATELLITE (space-to-Earth)
MOBILE except aeronautical mobile
Radiolocation 5.433

5.435</td><td>3600-3650
FIXED
FIXED-SATELLITE (space-to-Earth) US107 US245
MOBILE except aeronautical mobile

US105 US433</td><td rowspan="2">Satellite Communications (25)
Citizens Broadband (96)</td></tr>
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US109 US349</td><td>3650-3700
FIXED
FIXED-SATELLITE (space-to-Earth) NG169 NG185
MOBILE except aeronautical mobile

US109 US349</td></tr>
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MOBILE except aeronautical mobile</td><td>3700-4200</td><td>3700-4200
FIXED
FIXED-SATELLITE (space-to-Earth) NG180</td><td>Satellite Communications (25)
Fixed Microwave (101)</td></tr>
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AERONAUTICAL RADIONAVIGATION 5.438

5.439 5.440</td><td colspan="2">4200-4400
AERONAUTICAL RADIONAVIGATION

5.440 US261</td><td>Aviation (87)</td></tr>
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FIXED
MOBILE

US113 US245 US342</td><td>4400-4500</td><td></td></tr>
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MOBILE 5.440A</td><td>4500-4800
FIXED-SATELLITE (space-to-Earth) 5.441 US245</td><td></td></tr>
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MOBILE 5.440A 5.442
Radio astronomy

5.149 5.339 5.443</td><td>4800-4940

US113 US342</td><td></td></tr>
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5.339 US342 US385 G122</td><td>4940-4990
FIXED
MOBILE except aeronautical mobile

5.339 US342 US385</td><td>Public Safety Land Mobile (90Y)</td></tr>
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FIXED
MOBILE except aeronautical mobile
RADIO ASTRONOMY
Space research (passive)

5.149</td><td colspan="2">4990-5000
RADIO ASTRONOMY US74
Space research (passive)

US246</td><td></td></tr>
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5000-5010 AERONAUTICAL MOBILE-SATELLITE (R) 5.443AA AERONAUTICAL RADIONAVIGATION RADIONAVIGATION-SATELLITE (Earth-to-space)	5000-5010 AERONAUTICAL MOBILE (R) US115 AERONAUTICAL MOBILE-SATELLITE (R) 5.443AA AERONAUTICAL RADIONAVIGATION US260 RADIONAVIGATION-SATELLITE (Earth-to-space) US211		Aviation (87)
5010-5030 AERONAUTICAL MOBILE-SATELLITE (R) 5.443AA AERONAUTICAL RADIONAVIGATION RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space) 5.328B 5.443B	5010-5030 AERONAUTICAL MOBILE-SATELLITE (R) 5.443AA AERONAUTICAL RADIONAVIGATION US260 RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space) 5.443B US115 US211		
5030-5091 AERONAUTICAL MOBILE (R) 5.443C AERONAUTICAL MOBILE-SATELLITE (R) 5.443D AERONAUTICAL RADIONAVIGATION 5.444	5030-5091 AERONAUTICAL MOBILE (R) 5.443C AERONAUTICAL MOBILE-SATELLITE (R) 5.443D AERONAUTICAL RADIONAVIGATION US260 US211 US444		
5091-5150 AERONAUTICAL MOBILE 5.444B AERONAUTICAL MOBILE-SATELLITE (R) 5.443AA AERONAUTICAL RADIONAVIGATION 5.444 5.444A	5091-5150 AERONAUTICAL MOBILE US111 US444B AERONAUTICAL MOBILE-SATELLITE (R) 5.443AA AERONAUTICAL RADIONAVIGATION US260 US211 US344 US444 US444A		Satellite Communications (25) Aviation (87)
5150-5250 FIXED-SATELLITE (Earth-to-space) 5.447A MOBILE except aeronautical mobile 5.446A 5.446B AERONAUTICAL RADIONAVIGATION 5.446 5.446C 5.447 5.447B 5.447C	5150-5250 AERONAUTICAL RADIONAVIGATION US260 US211 US307 US344	5150-5250 FIXED-SATELLITE (Earth-to-space) 5.447A US344 AERONAUTICAL RADIONAVIGATION US260 5.447C US211 US307	RF Devices (15) Satellite Communications (25) Aviation (87)
5250-5255 EARTH EXPLORATION-SATELLITE (active) MOBILE except aeronautical mobile 5.446A 5.447F RADIOLOCATION SPACE RESEARCH 5.447D 5.447E 5.448 5.448A	5250-5255 EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION G59 SPACE RESEARCH (active) 5.447D 5.448A	5250-5255 Earth exploration-satellite (active) Radiolocation Space research	RF Devices (15) Private Land Mobile (90)
5255-5350 EARTH EXPLORATION-SATELLITE (active) MOBILE except aeronautical mobile 5.446A 5.447F RADIOLOCATION SPACE RESEARCH (active) 5.447E 5.448 5.448A	5255-5350 EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION G59 SPACE RESEARCH (active) 5.448A	5255-5350 Earth exploration-satellite (active) Radiolocation Space research (active) 5.448A	
5350-5460 EARTH EXPLORATION-SATELLITE (active) 5.448B RADIOLOCATION 5.448D AERONAUTICAL RADIONAVIGATION 5.449 SPACE RESEARCH (active) 5.448C	5350-5460 EARTH EXPLORATION-SATELLITE (active) 5.448B RADIOLOCATION G56 AERONAUTICAL RADIONAVIGATION 5.449 SPACE RESEARCH (active) US390 G130	5350-5460 AERONAUTICAL RADIONAVIGATION 5.449 Earth exploration-satellite (active) 5.448B Radiolocation Space research (active) US390	Aviation (87) Private Land Mobile (90)

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APPENDIX B. CELLULAR TELEPHONE POWER TRANSMISSION DATA

Appendix B contains a sample of the collected data used to calculate average power transmitted (P_t) for cellular telephones. The frequencies displayed are for the operating ranges of 699 MHz to 716 MHz, 814 MHz to 849 MHz, 1.71 GHz to 1.78 GHz, and 1.85 GHz to 1.915 GHz. The remaining operating bands data sets are similar to those displayed in the sample. Operating data was pulled from the FCC.io database and is a reflection of the operating characteristics for each cellular telephone in the sample.

Frequency >	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716
Power Outputs >	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66
Power Outputs >	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Power Outputs >	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56
Power Outputs >	71	71	71	71	71	55	55	55	55	55	55	55	55	55	55	55	55	55
Power Outputs >	62	62	62	62	62	68	68	68	68	68	68	68	68	68	68	68	68	68
Power Outputs >	64	64	64	64	64	56	56	56	56	56	56	56	56	56	56	56	56	56
Power Outputs >	53	53	53	53	53	71	71	71	71	71	71	71	71	71	71	71	71	71
Power Outputs >	56	56	56	56	56	62	62	62	62	62	62	62	62	62	62	62	62	62
Power Outputs >	47	47	47	47	47	58	58	58	58	58	58	58	58	58	58	58	58	58
Power Outputs >	66	66	66	66	66	71	71	71	71	71	71	71	71	71	71	71	71	71
Power Outputs >	56	56	56	56	56	64	64	64	64	64	64	64	64	64	64	64	64	64
Power Outputs >	78	78	78	78	78	53	53	53	53	53	53	53	53	53	53	53	53	53
Power Outputs >	65.3	65.3	65.3	65.3	65.3	65	65	65	65	65	65	65	65	65	65	65	65	65
Power Outputs >	81.7	81.7	81.7	81.7	81.7	54	54	54	54	54	54	54	54	54	54	54	54	54
Power Outputs >	71	71	71	71	71	56	56	56	56	56	56	56	56	56	56	56	56	56
Power Outputs >	19	34	34	34	34	47	47	47	47	47	47	47	47	47	47	47	47	47
Power Outputs >	35	27	27	27	27	66	66	66	66	66	66	66	66	66	66	66	66	66
Power Outputs >	55	19	19	19	19	56	56	56	56	56	56	56	56	56	56	56	56	56
Power Outputs >	54	19	19	19	19	65	65	65	65	65	65	65	65	65	65	65	65	65
Power Outputs >	46	23	23	23	23	53	53	53	53	53	53	53	53	53	53	53	53	53
Power Outputs >	49	72	23	23	23	78	78	78	78	78	78	78	78	78	78	78	78	78
Power Outputs >	42	61	15	15	15	65.3	65.3	65.3	65.3	65.3	65.3	65.3	65.3	65.3	65.3	65.3	65.3	65.3
Power Outputs >		74	72	72	72	81.7	81.7	81.7	81.7	81.7	81.7	81.7	81.7	81.7	81.7	81.7	81.7	81.7
Power Outputs >		62	61	61	61	71	71	71	71	71	71	71	71	71	71	71	71	71
Power Outputs >		35	74	74	74	75.9	75.9	75.9	75.9	75.9	75.9	75.9	75.9	75.9	75.9	75.9	75.9	75.9
Power Outputs >		55	62	62	62	63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1
Power Outputs >		54	35	69	69	80.7	80.7	80.7	80.7	80.7	80.7	80.7	80.7	80.7	80.7	80.7	80.7	80.7
Power Outputs >		46	55	57	57	67.1	67.1	67.1	67.1	67.1	67.1	67.1	67.1	67.1	67.1	67.1	67.1	67.1
Power Outputs >		49	54	35	35	49	49	49	49	49	49	49	49	49	49	49	49	49
Power Outputs >		42	46	55	55	53.7	53.7	53.7	53.7	53.7	53.7	53.7	53.7	53.7	53.7	53.7	53.7	53.7
Power Outputs >		42	49	54	54	114	114	114	114	114	114	114	114	114	114	114	114	114
Power Outputs >		34	42	46	46	34	34	230	230	230	230	230	230	230	230	230	34	35
Power Outputs >		80	51	49	49	27	27	225	225	225	225	225	225	225	225	225	27	55
Power Outputs >		65	43	42	42	34	34	34	34	34	225	225	225	34	34	34	19	54
Power Outputs >		51	42	51	51	26	26	27	27	27	200	200	200	27	27	27	19	46
Power Outputs >		76	34	43	43	19	19	34	34	34	34	34	34	19	19	19	23	76
Power Outputs >		60	36	55	55	19	19	26	26	26	27	27	27	19	19	19	72	60
Power Outputs >		68	43	46	46	23	23	19	19	19	34	34	34	23	23	23	61	
Power Outputs >		55	80	42	42	23	23	19	19	19	26	26	26	23	23	23	74	
Power Outputs >		74	65	34	34	15	15	23	23	23	19	19	19	15	15	15	62	
Power Outputs >		62	51	36	36	19	19	23	23	23	19	19	19	72	72	72	35	
Power Outputs >			81	43	43	23	23	15	15	15	23	23	23	61	61	61	55	

Power Outputs >			66	46	46	72	72	19	19	19	23	23	23	74	74	74	54	
Power Outputs >			52	39	39	61	61	23	23	23	15	15	15	62	62	62	46	
Power Outputs >			76	80	80	74	74	72	72	72	19	19	19	69	69	69	49	
Power Outputs >			60	65	65	62	62	61	61	61	23	23	23	57	57	57	42	
Power Outputs >			78	51	51	69	69	74	74	74	72	72	72	35	35	35	51	
Power Outputs >			63	81	81	57	57	62	62	62	61	61	61	55	55	55	43	
Power Outputs >			68	66	66	70	70	69	69	69	74	74	74	54	54	54	42	
Power Outputs >			55	52	52	58	58	57	57	57	62	62	62	46	46	46	34	
Power Outputs >			70	81	81	35	35	70	70	70	69	69	69	49	49	49	36	
Power Outputs >			58	66	66	55	55	58	58	58	57	57	57	42	42	42	43	
Power Outputs >			74	52	52	54	54	35	35	35	70	70	70	51	51	51	80	
Power Outputs >			62	76	76	46	46	55	55	55	58	58	58	43	43	43	65	
Power Outputs >			74	60	60	49	49	54	54	54	35	35	35	55	55	55	51	
Power Outputs >			62	78	78	42	42	46	46	46	55	55	55	46	46	46	81	
Power Outputs >				63	63	51	51	49	49	49	54	54	54	42	42	42	66	
Power Outputs >				79	79	43	43	42	42	42	46	46	46	34	34	34	52	
Power Outputs >				65	65	55	55	51	51	51	49	49	49	36	36	36	76	
Power Outputs >				68	68	46	46	43	43	43	42	42	42	43	43	43	60	
Power Outputs >				55	55	50	50	55	55	55	51	51	51	46	46	46	78	
Power Outputs >				70	70	43	43	46	46	46	43	43	43	39	39	39	63	
Power Outputs >				58	58	42	42	50	50	50	55	55	55	23	23	23	68	
Power Outputs >				75	75	34	34	43	43	43	46	46	46	22	22	22	55	
Power Outputs >				63	63	36	36	42	42	42	50	50	42	80	80	80	70	
Power Outputs >				74	74	43	43	34	34	34	43	43	34	65	65	65	58	
Power Outputs >				62	62	46	46	36	36	36	42	42	36	51	51	51	74	
Power Outputs >				74	74	39	39	43	43	43	34	34	43	81	81	81	62	
Power Outputs >				62	62	40	40	46	46	46	36	36	46	66	66	66	74	
Power Outputs >				78	78	36	36	39	39	39	43	43	39	52	52	52	62	
Power Outputs >				64	64	80	80	40	40	40	46	46	40	81	81	81		
Power Outputs >						65	65	36	36	36	39	39	36	66	66	66		
Power Outputs >						51	51	80	23	23	40	40	23	52	52	52		
Power Outputs >						81	81	65	22	22	36	36	22	61	61	76		
Power Outputs >						66	66	51	80	80	23	23	23	78	78	60		
Power Outputs >						52	52	81	65	65	22	22	24	49	49	78		
Power Outputs >						81	81	66	51	51	23	23	80	76	76	63		
Power Outputs >						66	66	52	81	81	24	24	65	60	60	79		
Power Outputs >						52	52	81	66	66	80	80	51	78	78	65		
Power Outputs >						81	81	66	52	52	65	65	81	63	63	68		
Power Outputs >						64	64	52	81	81	51	51	66	79	79	55		
Power Outputs >						51	51	81	66	66	81	81	52	65	65	70		
Power Outputs >						76	76	64	52	52	66	66	81	70	70	58		
Power Outputs >						60	60	51	81	81	52	52	66	57	57	75		

Power Outputs >						78	78	76	64	64	81	81	52	68	68	63		
Power Outputs >						63	63	60	51	51	66	66	81	55	55	74		
Power Outputs >						79	79	78	61	61	52	52	64	70	70	62		
Power Outputs >						65	65	63	78	78	81	81	51	58	58	74		
Power Outputs >						66	66	79	49	49	64	64	61	75	75	62		
Power Outputs >						82	82	65	76	76	51	51	78	63	63	78		
Power Outputs >						68	68	66	60	60	61	61	49	74	74	64		
Power Outputs >						55	55	82	78	78	78	78	76	62	62	124		
Power Outputs >						70	70	68	63	63	49	49	61	74	74	93		
Power Outputs >						58	58	55	79	79	76	76	48	62	62	86		
Power Outputs >						75	75	70	65	65	61	61	76	78	78	51		
Power Outputs >						63	63	58	66	66	48	48	60	64	64	93		
Power Outputs >						73	73	75	82	82	76	76	78	124	124			
Power Outputs >						56	56	63	70	70	60	60	63	93	93			
Power Outputs >						74	74	73	57	57	78	78	79	86	86			
Power Outputs >						62	62	56	68	68	63	63	65	51	51			
Power Outputs >						74	74	74	55	55	79	79	66	93	93			
Power Outputs >						62	62	62	70	70	65	65	82					
Power Outputs >						78	78	74	58	58	66	66	70					
Power Outputs >						64	64	62	75	75	82	82	57					
Power Outputs >						79	79	78	63	63	70	70	71					
Power Outputs >						65	65	64	73	73	57	57	59					
Power Outputs >						29	29	79	56	56	71	71	68					
Power Outputs >								65	74	74	59	59	55					
Power Outputs >								29	62	62	68	68	70					
Power Outputs >									74	74	55	55	58					
Power Outputs >									62	62	70	70	75					
Power Outputs >									78	78	58	58	63					
Power Outputs >									64	64	75	75	73					
Power Outputs >									79	79	63	63	56					
Power Outputs >									65	65	73	73	74					
Power Outputs >									124	124	56	56	62					
Power Outputs >									93	93	74	74	74					
Power Outputs >									29	29	62	62	62					
Power Outputs >									86	86	74	74	78					
Power Outputs >									51	51	62	62	64					
Power Outputs >									93	93	78	78	79					
Power Outputs >											64	64	65					
Power Outputs >											79	79	124					
Power Outputs >											65	65	93					
Power Outputs >											124	124	116					
Power Outputs >											93	93	92					

Power Outputs >											29	29	51					
Power Outputs >											86	47	88					
Power Outputs >											51	30	52					
Power Outputs >											88	86	93					
Power Outputs >											52	51	89					
Power Outputs >											93	88						
Power Outputs >											89	52						
Power Outputs >												93						
Power Outputs >												89						
Average Power Transmitted (Pt)	85.2	71.4	66.9	66.0	66.0	63.4	63.4	66.4	66.5	66.5	68.7	68.2	69.0	69.3	69.3	69.7	68.2	80.3

Frequency >	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837
Power Outputs >	83	83	83	83	83	83	83	83	83	83	83	144	144	144	144	144	144	144	144	144	144	144	144	144
Power Outputs >	65	65	65	65	65	65	65	65	65	65	65	88	88	88	88	88	88	88	88	88	88	88	88	88
Power Outputs >	71	71	71	71	71	71	71	71	71	71	71	85	85	85	85	85	85	85	85	85	85	85	85	85
Power Outputs >	105	105	83	83	83	83	83	83	83	83	83	89	89	89	89	89	89	89	89	89	89	89	89	89
Power Outputs >	87	87	105	105	105	105	105	105	105	105	105	72	72	72	72	72	72	72	72	72	72	72	72	72
Power Outputs >	103	103	87	87	87	87	87	87	87	87	87	76	76	76	76	76	76	76	76	76	76	76	76	76
Power Outputs >	166	166	103	103	103	103	103	103	103	103	103	122	122	122	122	122	122	122	122	122	122	122	122	122
Power Outputs >	113	113	166	166	166	166	166	166	166	166	166	123	123	123	123	123	123	123	123	123	123	123	123	123
Power Outputs >	94	94	113	113	113	113	113	113	113	113	113	98	98	98	98	98	98	98	98	98	98	98	98	98
Power Outputs >	118	118	94	94	94	94	94	94	94	94	94	102	102	102	102	102	102	102	102	102	102	102	102	102
Power Outputs >	98	98	118	118	118	118	118	118	118	118	118	121	121	121	121	121	121	121	121	121	121	121	121	121
Power Outputs >	120	120	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98
Power Outputs >	110	110	120	120	120	120	120	120	120	120	120	145	145	145	145	145	145	145	145	145	145	145	145	145
Power Outputs >	150	150	110	110	110	110	110	110	110	110	110	118	118	118	118	118	118	118	118	118	118	118	118	118
Power Outputs >	137	137	150	150	150	150	150	150	150	150	150	109	109	109	109	109	109	109	109	109	109	109	109	109
Power Outputs >	114	114	137	137	137	137	137	137	137	137	137	87	87	87	87	87	87	87	87	87	87	87	87	87
Power Outputs >	163	163	114	114	114	114	114	114	114	114	114	118	118	118	118	118	118	118	118	118	118	118	118	118
Power Outputs >	136	136	163	163	163	163	163	163	163	163	163	97	97	97	97	97	97	97	97	97	97	97	97	97
Power Outputs >	115.1	115.1	136	136	136	136	136	136	136	136	136	128	128	128	128	128	128	128	128	128	128	128	128	128
Power Outputs >	95.7	95.7	98	98	98	98	98	98	98	98	98	125	125	125	125	125	125	125	125	125	125	125	125	125
Power Outputs >	118	118	115.1	115.1	115.1	115.1	115.1	115.1	115.1	115.1	115.1	102.6	102.6	102.6	102.6	102.6	102.6	102.6	102.6	102.6	102.6	102.6	102.6	102.6
Power Outputs >	98.2	98.2	95.7	95.7	95.7	95.7	95.7	95.7	95.7	95.7	95.7	149.6	149.6	149.6	149.6	149.6	149.6	149.6	149.6	149.6	149.6	149.6	149.6	149.6
Power Outputs >	74	74	118	118	118	118	118	118	118	118	118	123	123	123	123	123	123	123	123	123	123	123	123	123
Power Outputs >	70	70	98.2	98.2	98.2	98.2	98.2	98.2	98.2	98.2	98.2	168	168	168	168	168	168	168	168	168	168	168	168	168
Power Outputs >	113	113	74	113	113	113	113	113	113	113	113	111	111	111	111	111	111	111	111	111	111	111	111	111
Power Outputs >	188	188	70	74	74	74	74	74	74	74	74	104	104	104	104	104	104	104	104	104	104	104	104	104
Power Outputs >	229	229	113	70	70	70	70	70	70	70	70	88	88	88	88	88	88	88	88	88	88	88	88	88
Power Outputs >	226	226	188	113	113	113	113	113	113	113	113	98	98	98	98	98	98	98	98	98	98	98	98	98
Power Outputs >	189	189	229	223.9	223.9	223.9	223.9	223.9	223.9	223.9	223.9	90	90	90	90	90	90	90	90	90	90	90	90	90
Power Outputs >		195	233	275.4	275.4	275.4	275.4	275.4	275.4	275.4	275.4	91	91	91	91	91	91	91	91	91	91	91	91	91
Power Outputs >		167	187	107.2	107.2	107.2	107.2	107.2	107.2	107.2	107.2	635	635	635	635	635	635	635	635	635	635	635	635	635
Power Outputs >		233	203	138	138	138	138	138	138	138	138	120.2	120.2	120.2	120.2	120.2	120.2	120.2	120.2	120.2	120.2	120.2	120.2	120.2
Power Outputs >		196	161	277	277	277	277	277	277	277	277	131.8	131.8	131.8	131.8	131.8	131.8	131.8	131.8	131.8	131.8	131.8	131.8	131.8
Power Outputs >		90	226	334	334	334	334	334	334	334	334	123	123	123	123	123	123	123	123	123	123	123	123	123
Power Outputs >		71	189	188	188	10	188	188	188	188	171	115	115	115	115	115	115	115	115	115	115	115	115	115
Power Outputs >		57	195	229	229	8	229	229	229	229	156	112	112	112	112	112	112	112	112	112	112	112	112	112
Power Outputs >		76	167	233	233	188	233	233	233	233	197	126	126	126	126	126	126	126	126	126	126	126	126	126
Power Outputs >		60	199	187	187	229	187	187	187	187	168	115	115	115	115	115	115	115	115	115	115	115	115	115
Power Outputs >			166	227	227	233	227	227	227	203	171	171	171	171	171	171	171	171	171	171	171	171	171	171
Power Outputs >			233	198	198	187	198	198	198	161	156	156	156	156	156	156	156	156	156	156	156	156	156	156
Power Outputs >			196	203	203	227	203	203	127	226	1574	197	197	197	197	197	197	197	197	197	197	197	197	197
Power Outputs >			245	161	161	198	161	161	96	189	841	168	168	168	168	168	168	168	168	168	168	168	168	168

Power Outputs >			199	200	200	215	200	200	203	195	519	171	171	171	171	171	171	171	171	171	171	171	171	171
Power Outputs >			90	184	184	193	184	184	161	167	1660	156	156	156	156	156	156	156	156	156	156	156	156	156
Power Outputs >			71	226	226	203	226	226	200	199	920	192	192	192	192	192	192	192	192	192	192	192	192	192
Power Outputs >			57	189	189	161	189	189	184	166	186	1574	194	194	194	194	194	194	194	194	194	194	194	194
Power Outputs >			72	195	195	200	195	195	73	233	91	841	181	181	181	181	181	181	181	181	181	181	181	181
Power Outputs >			57	167	167	184	167	167	60	196	70	519	1574	1574	1574	175	175	175	175	175	175	175	175	175
Power Outputs >			91	199	199	199	199	199	226	245	323	1660	841	841	841	154	154	154	154	154	154	154	154	154
Power Outputs >			76	166	166	163	166	166	189	199	14	920	519	519	519	1574	1574	1574	1574	1574	1574	1574	1574	1574
Power Outputs >			60	198	198	226	198	198	76	90	140	186	452	452	452	841	841	841	841	841	841	841	841	841
Power Outputs >			79	181	181	189	181	181	90	71	171	91	1660	1660	1660	519	519	519	519	519	519	519	519	519
Power Outputs >			63	233	233	195	233	103	195	57	226	70	920	920	920	452	452	452	452	452	452	452	452	452
Power Outputs >				196	196	167	196	88	167	72	189	70	380	380	380	1660	1660	1660	1660	1660	1660	1660	1660	1660
Power Outputs >				245	245	199	245	233	199	57	1979	93	186	186	186	920	920	920	920	920	920	920	920	920
Power Outputs >				199	199	166	199	196	166	91	545	323	91	91	91	380	380	380	380	380	380	380	380	380
Power Outputs >				247	247	198	247	245	198	82	828	14	70	70	70	186	186	186	186	186	186	186	186	186
Power Outputs >				198	198	181	198	199	181	76	143	140	70	70	70	91	91	91	91	91	91	91	91	91
Power Outputs >				90	90	198	90	247	233	60		171	93	93	93	70	70	70	70	70	70	70	70	70
Power Outputs >				71	71	171	71	198	196	79		68	90	90	90	70	70	70	70	70	70	70	70	70
Power Outputs >				57	57	233	57	90	245	63		56	83	83	83	93	93	93	93	93	93	93	93	93
Power Outputs >				72	72	196	72	71	199	33		101	64	64	64	90	90	90	90	90	90	90	90	90
Power Outputs >				57	57	245	57	57	247			86	323	323	323	83	83	83	83	83	83	83	83	83
Power Outputs >				91	91	199	91	72	198			115	77	77	77	64	64	64	64	64	64	64	64	64
Power Outputs >				57	57	247	57	57	90			96	14	14	14	88	88	88	88	88	88	88	88	88
Power Outputs >				91	91	198	91	91	71			63	140	140	140	69	69	69	69	69	69	69	69	69
Power Outputs >				72	72	239	72	57	57			51	171	171	171	323	323	323	323	323	323	323	323	323
Power Outputs >				76	82	198	82	91	72			1979	160	160	160	77	77	77	77	77	77	77	77	77
Power Outputs >				60	76	90	76	72	57			545	132	132	132	14	14	14	14	14	14	14	14	14
Power Outputs >				79	60	71	60	82	91			71	68	151	151	8	8	8	8	8	8	8	8	8
Power Outputs >				63	79	57	79	76	57			56	56	129	129	7	7	7	7	7	7	7	7	7
Power Outputs >				81	63	72	63	60	91			66	71	68	68	140	140	6	6	6	6	6	6	6
Power Outputs >				64	81	57	81	79	72			54	58	56	56	171	171	4	4	4	4	4	4	4
Power Outputs >					64	91	64	63	82			92	101	71	71	160	160	140	140	140	140	140	140	140
Power Outputs >					33	57	33	81	76			76	86	58	58	132	132	171	171	171	171	171	171	171
Power Outputs >						91		64	60			120	114	70	70	151	151	160	160	160	160	160	160	160
Power Outputs >						72		33	79			104	115	58	58	129	129	132	132	132	132	132	132	132
Power Outputs >						82			63			828	96	101	101	170	170	151	151	151	151	151	151	151
Power Outputs >						91			81			143	141	86	86	122	122	129	129	129	129	129	129	129
Power Outputs >						72			64			127	118	114	114	68	68	170	170	170	170	170	170	170
Power Outputs >						57			33			63	63	115	115	56	56	122	122	122	122	122	122	122
Power Outputs >						76						135	51	96	96	71	71	158	158	158	158	158	158	158
Power Outputs >						60						71	70	141	141	58	58	122	122	122	122	122	122	122
Power Outputs >						79						89	57	118	118	70	70	68	68	68	68	68	68	68

Power Outputs >						63							98	154	154	58	58	56	56	56	56	56	56	56
Power Outputs >						81							1979	128	128	74	74	71	71	71	71	71	71	71
Power Outputs >						64							545	63	63	61	61	58	58	58	58	58	58	58
Power Outputs >						33							237	51	51	101	101	70	70	70	70	70	70	70
Power Outputs >						83							71	70	70	86	86	58	58	58	58	58	58	58
Power Outputs >						65							56	57	57	114	114	74	74	74	74	74	74	74
Power Outputs >													91	69	69	115	115	61	61	61	61	61	61	61
Power Outputs >													72	59	59	96	96	101	74	74	74	74	74	74
Power Outputs >													57	98	98	141	141	86	61	61	61	61	61	61
Power Outputs >													66	44	44	118	118	114	101	101	101	101	101	101
Power Outputs >													54	42	42	154	154	115	86	86	86	86	86	86
Power Outputs >													67	1979	1979	128	128	96	114	114	114	114	114	114
Power Outputs >													56	545	545	141	141	141	115	115	115	115	115	115
Power Outputs >													92	237	237	120	120	118	96	96	96	96	96	96
Power Outputs >													76	71	71	63	63	154	141	141	141	141	141	141
Power Outputs >													91	56	56	51	51	128	118	118	118	118	118	118
Power Outputs >													75	91	91	70	70	141	154	154	154	154	154	154
Power Outputs >													120	72	72	57	57	120	128	128	128	128	128	128
Power Outputs >													104	57	57	69	69	63	141	141	141	141	141	141
Power Outputs >													118	90	90	59	59	51	120	120	120	120	120	120
Power Outputs >													101	72	72	72	72	70	120	120	120	120	120	120
Power Outputs >													63	57	57	58	58	57	101	101	101	101	101	101
Power Outputs >													47	66	66	98	98	69	63	63	63	63	63	63
Power Outputs >													828	54	54	44	44	59	51	51	51	51	51	51
Power Outputs >													143	67	67	42	42	72	70	70	70	70	70	70
Power Outputs >													127	56	56	43	43	58	57	57	57	57	57	57
Power Outputs >													63	61	61	40	40	98	69	69	69	69	69	69
Power Outputs >													94	49	49	1979	1979	44	59	59	59	59	59	59
Power Outputs >													84	92	92	545	545	42	72	72	72	72	72	72
Power Outputs >													135	76	76	237	237	43	58	58	58	58	58	58
Power Outputs >													71	91	91	71	71	40	55	55	55	55	55	55
Power Outputs >													134	75	75	56	56	1979	44	44	44	44	44	44
Power Outputs >													71	108	108	91	91	545	98	98	98	98	98	98
Power Outputs >													89	90	90	72	72	237	44	44	44	44	44	44
Power Outputs >													86	120	120	57	57	71	42	42	42	42	42	42
Power Outputs >													106	104	104	90	90	56	43	43	43	43	43	43
Power Outputs >														118	118	72	72	91	40	40	40	40	40	40
Power Outputs >														101	101	57	57	72	1979	1979	1979	1979	1979	1979
Power Outputs >														123	123	91	91	57	545	545	545	545	545	545
Power Outputs >														101	101	73	73	90	237	237	237	237	237	237
Power Outputs >														63	63	58	58	72	71	71	71	71	71	71
Power Outputs >														47	47	66	66	57	56	56	56	56	56	56

Power Outputs >														66	66	54	54	91	91	91	91	91	91	91
Power Outputs >														47	47	67	67	73	72	72	72	72	72	72
Power Outputs >														828	828	56	56	58	57	57	57	57	57	57
Power Outputs >														143	143	61	61	66	90	90	90	90	90	90
Power Outputs >														127	127	49	49	54	72	72	72	72	72	72
Power Outputs >														63	63	50	50	67	57	57	57	57	57	57
Power Outputs >														94	94	63	63	56	91	91	91	91	91	91
Power Outputs >														84	84	92	92	61	73	73	73	73	73	73
Power Outputs >														135	135	76	76	49	58	58	58	58	58	58
Power Outputs >														71	71	91	91	50	72	72	72	72	72	72
Power Outputs >														134	134	75	75	63	91	91	91	91	91	91
Power Outputs >														71	71	108	108	92	58	58	58	58	58	58
Power Outputs >														123	123	90	90	76	66	66	66	66	66	66
Power Outputs >														76	76	89	89	91	54	54	54	54	54	54
Power Outputs >														89	89	74	74	75	67	67	67	67	67	67
Power Outputs >														86	86	120	120	108	56	56	56	56	56	56
Power Outputs >														106	106	104	104	90	61	61	61	61	61	61
Power Outputs >														86	86	118	118	89	49	49	49	49	49	49
Power Outputs >																101	101	74	50	50	50	50	50	50
Power Outputs >																123	123	120	63	63	63	63	63	63
Power Outputs >																101	101	104	63	63	63	63	63	63
Power Outputs >																118	118	118	51	51	51	51	51	51
Power Outputs >																98	98	101	92	92	92	92	92	92
Power Outputs >																63	63	123	76	76	76	76	76	76
Power Outputs >																47	47	101	91	91	91	91	91	91
Power Outputs >																66	66	118	75	75	75	75	75	75
Power Outputs >																47	47	98	108	108	108	108	108	108
Power Outputs >																60	60	63	90	90	90	90	90	90
Power Outputs >																44	44	47	89	89	89	89	89	89
Power Outputs >																828	828	66	74	74	74	74	74	74
Power Outputs >																143	143	47	120	120	120	120	120	120
Power Outputs >																127	127	60	104	104	104	104	104	104
Power Outputs >																63	63	44	118	118	118	118	118	118
Power Outputs >																94	94	828	101	101	101	101	101	101
Power Outputs >																84	84	143	123	123	123	123	123	123
Power Outputs >																87	87	127	101	101	101	101	101	101
Power Outputs >																56	56	63	118	118	118	118	118	118
Power Outputs >																135	135	94	98	98	98	98	98	98
Power Outputs >																71	71	84	63	63	63	63	63	63
Power Outputs >																134	134	87	47	47	47	47	47	47
Power Outputs >																71	71	56	66	66	66	66	66	66
Power Outputs >																123	123	135	47	47	47	47	47	47

Power Outputs >															76	76	71	60	60	60	60	60	60	60
Power Outputs >															128	128	134	44	44	44	44	44	44	44
Power Outputs >															73	73	71	828	828	828	828	828	828	828
Power Outputs >															89	89	123	143	143	143	143	143	143	143
Power Outputs >															86	86	76	127	127	127	127	127	127	127
Power Outputs >															106	106	128	63	63	63	63	63	63	63
Power Outputs >															86	86	73	94	94	94	94	94	94	94
Power Outputs >															97	97	89	84	84	84	84	84	84	84
Power Outputs >																	86	87	87	87	87	87	87	87
Power Outputs >																	106	56	56	56	56	56	56	56
Power Outputs >																	86	135	135	135	135	135	135	135
Power Outputs >																	97	71	71	71	71	71	71	71
Power Outputs >																		134	134	134	134	134	134	134
Power Outputs >																		71	71	71	71	71	71	71
Power Outputs >																		123	123	123	123	123	123	123
Power Outputs >																		76	76	76	76	76	76	76
Power Outputs >																		128	128	128	128	128	128	128
Power Outputs >																		73	73	73	73	73	73	73
Power Outputs >																		89	89	89	89	89	89	89
Power Outputs >																		86	86	86	86	86	86	86
Power Outputs >																		106	106	106	106	106	106	106
Power Outputs >																		86	86	86	86	86	86	86
Power Outputs >																		97	97	97	97	97	97	97
Average Power Transmitted (Pt)	123.5	128.9	141.0	138.8	137.5	138.8	137.7	135.0	135.7	272.5	212.9	184.0	167.6	167.6	152.2	152.2	150.4	145.9	145.9	145.9	145.9	145.9	145.9	145.9

Frequency >	838	839	840	841	842	843	844	845	846	847	848	849
Power Outputs >	144	144	144	144	144	144	144	144	144	144	144	144
Power Outputs >	88	88	88	88	88	88	88	88	88	88	88	88
Power Outputs >	85	85	85	85	85	85	85	85	85	85	85	85
Power Outputs >	89	89	89	89	89	89	89	89	89	89	89	89
Power Outputs >	72	72	72	72	72	72	72	72	72	72	72	72
Power Outputs >	76	76	76	76	76	76	76	76	76	76	76	76
Power Outputs >	122	122	122	122	122	122	122	122	122	122	122	122
Power Outputs >	123	123	123	123	123	123	123	123	123	123	123	123
Power Outputs >	98	98	98	98	98	98	98	98	98	98	98	98
Power Outputs >	102	102	102	102	102	102	102	102	102	102	102	102
Power Outputs >	121	121	121	121	121	121	121	121	121	121	121	121
Power Outputs >	98	98	98	98	98	98	98	98	98	98	98	98
Power Outputs >	145	145	145	145	145	145	145	145	145	145	145	145
Power Outputs >	118	118	118	118	118	118	118	118	118	118	118	118
Power Outputs >	109	109	109	109	109	109	109	109	109	109	109	109
Power Outputs >	87	87	87	87	87	87	87	87	87	87	87	87
Power Outputs >	118	118	118	118	118	118	118	118	118	118	118	118
Power Outputs >	97	97	97	97	97	97	97	97	97	97	97	97
Power Outputs >	128	128	128	128	128	128	128	128	128	128	128	128
Power Outputs >	125	125	125	125	125	125	125	125	125	125	125	125
Power Outputs >	102.6	102.6	102.6	102.6	102.6	102.6	102.6	102.6	102.6	102.6	102.6	102.6
Power Outputs >	149.6	149.6	149.6	149.6	149.6	149.6	149.6	149.6	149.6	149.6	149.6	149.6
Power Outputs >	123	123	123	123	123	123	123	123	123	123	123	123
Power Outputs >	168	168	168	168	168	168	168	168	168	168	168	168
Power Outputs >	111	111	111	111	111	111	111	111	111	111	111	111
Power Outputs >	104	104	104	104	104	104	104	104	104	104	104	104
Power Outputs >	88	88	88	88	88	88	88	88	88	88	88	88
Power Outputs >	98	98	98	98	98	98	98	98	98	98	98	98
Power Outputs >	90	90	90	90	90	90	90	90	90	90	90	90
Power Outputs >	91	91	91	91	91	91	91	91	91	91	91	91
Power Outputs >	635	635	635	635	635	635	635	635	635	635	635	635
Power Outputs >	120.2	120.2	120.2	120.2	120.2	120.2	120.2	120.2	120.2	120.2	120.2	120.2
Power Outputs >	131.8	131.8	131.8	131.8	131.8	131.8	131.8	131.8	131.8	131.8	131.8	131.8
Power Outputs >	123	123	123	123	123	123	123	123	123	123	123	123
Power Outputs >	115	115	115	115	115	115	115	115	115	115	115	115
Power Outputs >	112	112	112	112	112	112	112	112	112	112	112	112
Power Outputs >	126	126	126	126	126	126	126	126	126	126	126	126
Power Outputs >	115	115	115	115	115	115	115	115	115	115	115	115
Power Outputs >	171	171	171	171	171	171	171	171	171	171	171	171
Power Outputs >	156	156	156	156	156	156	156	156	156	156	156	156
Power Outputs >	197	197	197	197	197	197	197	197	197	197	197	197
Power Outputs >	168	168	168	168	168	168	168	168	168	168	168	168

Power Outputs >	171	171	171	171	171	171	171	171	171	171	171	171
Power Outputs >	156	156	156	156	156	156	156	156	156	156	156	156
Power Outputs >	192	192	192	192	192	192	192	192	192	192	192	1574
Power Outputs >	194	194	194	194	194	194	194	194	194	194	1574	841
Power Outputs >	181	181	181	181	181	181	181	181	181	181	841	519
Power Outputs >	175	175	175	175	175	175	175	1574	1574	1574	519	323
Power Outputs >	154	154	154	154	154	154	154	841	841	841	1660	101
Power Outputs >	1574	1574	1574	1574	1574	1574	1574	519	519	519	920	86
Power Outputs >	841	841	841	841	841	841	841	452	452	1660	186	1979
Power Outputs >	519	519	519	519	519	519	519	1660	1660	920	91	545
Power Outputs >	452	452	452	452	452	452	452	920	920	380	70	828
Power Outputs >	1660	1660	1660	1660	1660	1660	1660	380	380	186	323	143
Power Outputs >	920	920	920	920	920	920	920	186	186	91	140	
Power Outputs >	380	380	380	380	380	380	380	91	91	70	171	
Power Outputs >	186	186	186	186	186	186	186	70	70	70	160	
Power Outputs >	91	91	91	91	91	91	91	70	70	93	132	
Power Outputs >	70	70	70	70	70	70	70	93	93	90	68	
Power Outputs >	70	70	70	70	70	70	70	90	90	83	56	
Power Outputs >	93	93	93	93	93	93	93	83	83	64	71	
Power Outputs >	90	90	90	90	90	90	90	64	64	323	58	
Power Outputs >	83	83	83	83	83	83	83	323	323	77	101	
Power Outputs >	64	64	64	64	64	64	64	77	77	14	86	
Power Outputs >	88	88	88	88	88	88	88	14	14	140	115	
Power Outputs >	69	69	69	69	69	69	69	140	140	171	96	
Power Outputs >	323	323	323	323	323	323	323	171	171	160	141	
Power Outputs >	77	77	77	77	77	77	77	160	160	132	118	
Power Outputs >	14	14	14	14	14	14	14	132	132	151	63	
Power Outputs >	8	8	8	8	8	8	8	151	151	129	51	
Power Outputs >	7	7	7	7	7	7	7	129	129	68	1979	
Power Outputs >	6	6	6	6	6	140	140	68	68	56	545	
Power Outputs >	4	4	4	4	4	171	171	56	56	71	71	
Power Outputs >	140	140	140	140	140	160	160	71	71	58	56	
Power Outputs >	171	171	171	171	171	132	132	58	58	70	91	
Power Outputs >	160	160	160	160	160	151	151	70	70	58	72	
Power Outputs >	132	132	132	132	132	129	129	58	58	101	57	
Power Outputs >	151	151	151	151	151	170	170	101	101	86	66	
Power Outputs >	129	129	129	129	129	122	122	86	86	114	54	
Power Outputs >	170	170	170	170	170	68	68	114	114	115	67	
Power Outputs >	122	122	122	122	122	56	56	115	115	96	56	
Power Outputs >	158	158	158	158	158	71	71	96	96	141	92	
Power Outputs >	122	122	122	122	122	58	58	141	141	118	76	
Power Outputs >	68	68	68	68	68	70	70	118	118	154	91	

Power Outputs >	56	56	56	56	56	58	58	154	154	128	75	
Power Outputs >	71	71	71	71	71	74	74	128	128	63	120	
Power Outputs >	58	58	58	58	58	61	61	63	63	51	104	
Power Outputs >	70	70	70	70	70	101	101	51	51	70	118	
Power Outputs >	58	58	58	58	58	86	86	70	70	57	101	
Power Outputs >	74	74	74	74	74	114	114	57	57	98	63	
Power Outputs >	61	61	61	61	61	115	115	69	69	44	47	
Power Outputs >	74	74	74	74	74	96	96	59	59	42	828	
Power Outputs >	61	61	61	61	61	141	141	98	98	1979	143	
Power Outputs >	101	101	101	101	101	118	118	44	44	545	127	
Power Outputs >	86	86	86	86	86	154	154	42	42	237	63	
Power Outputs >	114	114	114	114	114	128	128	1979	1979	71	94	
Power Outputs >	115	115	115	115	115	141	141	545	545	56	135	
Power Outputs >	96	96	96	96	96	120	120	237	237	91	71	
Power Outputs >	141	141	141	141	141	63	63	71	71	72	134	
Power Outputs >	118	118	118	118	118	51	51	56	56	57	71	
Power Outputs >	154	154	154	154	154	70	70	91	91	90	89	
Power Outputs >	128	128	128	128	128	57	57	72	72	72	86	
Power Outputs >	141	141	141	141	141	69	69	57	57	57		
Power Outputs >	120	120	120	120	120	59	59	90	90	66		
Power Outputs >	120	120	120	120	120	72	72	72	72	54		
Power Outputs >	101	101	101	101	101	58	58	57	57	67		
Power Outputs >	63	63	63	63	63	98	98	66	66	56		
Power Outputs >	51	51	51	51	51	44	44	54	54	61		
Power Outputs >	70	70	70	70	70	42	42	67	67	49		
Power Outputs >	57	57	57	57	57	43	43	56	56	92		
Power Outputs >	69	69	69	69	69	40	40	61	61	76		
Power Outputs >	59	59	59	59	59	1979	1979	49	49	91		
Power Outputs >	72	72	72	72	72	545	545	92	92	75		
Power Outputs >	58	58	58	58	58	237	237	76	76	108		
Power Outputs >	55	55	55	55	55	71	71	91	91	90		
Power Outputs >	44	44	44	44	44	56	56	75	75	120		
Power Outputs >	98	98	98	98	98	91	91	108	108	104		
Power Outputs >	44	44	44	44	44	72	72	90	90	118		
Power Outputs >	42	42	42	42	42	57	57	120	120	101		
Power Outputs >	43	43	43	43	43	90	90	104	104	123		
Power Outputs >	40	40	40	40	40	72	72	118	118	101		
Power Outputs >	1979	1979	1979	1979	1979	57	57	101	101	63		
Power Outputs >	545	545	545	545	545	91	91	123	123	47		
Power Outputs >	237	237	237	237	237	73	73	101	101	66		
Power Outputs >	71	71	71	71	71	58	58	63	63	47		
Power Outputs >	56	56	56	56	56	66	66	47	47	828		

Power Outputs >	91	91	91	91	91	54	54	66	66	143		
Power Outputs >	72	72	72	72	72	67	67	47	47	127		
Power Outputs >	57	57	57	57	57	56	56	828	828	63		
Power Outputs >	90	90	90	90	90	61	61	143	143	94		
Power Outputs >	72	72	72	72	72	49	49	127	127	84		
Power Outputs >	57	57	57	57	57	50	50	63	63	135		
Power Outputs >	91	91	91	91	91	63	63	94	94	71		
Power Outputs >	73	73	73	73	73	92	92	84	84	134		
Power Outputs >	58	58	58	58	58	76	76	135	135	71		
Power Outputs >	72	72	72	72	72	91	91	71	71	123		
Power Outputs >	91	91	91	91	91	75	75	134	134	76		
Power Outputs >	58	58	58	58	58	108	108	71	71	89		
Power Outputs >	66	66	66	66	66	90	90	123	123	86		
Power Outputs >	54	54	54	54	54	89	89	76	76	106		
Power Outputs >	67	67	67	67	67	74	74	89	89	86		
Power Outputs >	56	56	56	56	56	120	120	86	86			
Power Outputs >	61	61	61	61	61	104	104	106	106			
Power Outputs >	49	49	49	49	49	118	118	86	86			
Power Outputs >	50	50	50	50	50	101	101					
Power Outputs >	63	63	63	63	63	123	123					
Power Outputs >	63	63	63	63	63	101	101					
Power Outputs >	51	51	51	51	51	118	118					
Power Outputs >	92	92	92	92	92	98	98					
Power Outputs >	76	76	76	76	76	63	63					
Power Outputs >	91	91	91	91	91	47	47					
Power Outputs >	75	75	75	75	75	66	66					
Power Outputs >	108	108	108	108	108	47	47					
Power Outputs >	90	90	90	90	90	60	60					
Power Outputs >	89	89	89	89	89	44	44					
Power Outputs >	74	74	74	74	74	828	828					
Power Outputs >	120	120	120	120	120	143	143					
Power Outputs >	104	104	104	104	104	127	127					
Power Outputs >	118	118	118	118	118	63	63					
Power Outputs >	101	101	101	101	101	94	94					
Power Outputs >	123	123	123	123	123	84	84					
Power Outputs >	101	101	101	101	101	87	87					
Power Outputs >	118	118	118	118	118	56	56					
Power Outputs >	98	98	98	98	98	135	135					
Power Outputs >	63	63	63	63	63	71	71					
Power Outputs >	47	47	47	47	47	134	134					
Power Outputs >	66	66	66	66	66	71	71					
Power Outputs >	47	47	47	47	47	123	123					

Power Outputs >	60	60	60	60	60	76	76					
Power Outputs >	44	44	44	44	44	128	128					
Power Outputs >	828	828	828	828	828	73	73					
Power Outputs >	143	143	143	143	143	89	89					
Power Outputs >	127	127	127	127	127	86	86					
Power Outputs >	63	63	63	63	63	106	106					
Power Outputs >	94	94	94	94	94	86	86					
Power Outputs >	84	84	84	84	84	97	97					
Power Outputs >	87	87	87	87	87							
Power Outputs >	56	56	56	56	56							
Power Outputs >	135	135	135	135	135							
Power Outputs >	71	71	71	71	71							
Power Outputs >	134	134	134	134	134							
Power Outputs >	71	71	71	71	71							
Power Outputs >	123	123	123	123	123							
Power Outputs >	76	76	76	76	76							
Power Outputs >	128	128	128	128	128							
Power Outputs >	73	73	73	73	73							
Power Outputs >	89	89	89	89	89							
Power Outputs >	86	86	86	86	86							
Power Outputs >	106	106	106	106	106							
Power Outputs >	86	86	86	86	86							
Power Outputs >	97	97	97	97	97							
Average Power Transmitted (Pt)	145.9	145.9	145.9	145.9	145.9	152.2	152.2	167.6	167.6	167.0	192.3	235.3

Frequency >	1.85	1.855	1.86	1.865	1.87	1.875	1.88	1.885	1.89	1.895	1.9	1.905	1.91	1.915
Power Outputs >	253	253	253	253	253	253	253	253	253	253	253	253	253	251
Power Outputs >	257	257	257	257	257	257	257	257	257	257	257	257	257	209
Power Outputs >	214	214	214	214	214	214	214	214	214	214	214	214	214	224
Power Outputs >	219	219	219	219	219	219	219	219	219	219	219	219	219	191
Power Outputs >	251	251	251	251	251	251	251	251	251	251	251	251	251	195
Power Outputs >	209	209	209	209	209	209	209	209	209	209	209	209	209	162
Power Outputs >	224	224	224	224	224	224	224	224	224	224	224	224	224	221
Power Outputs >	217	217	217	217	217	217	217	217	217	217	217	217	217	183
Power Outputs >	209	209	209	209	209	209	209	209	209	209	209	209	209	364
Power Outputs >	182	182	182	182	182	182	182	182	182	182	182	182	182	270
Power Outputs >	191	191	191	191	191	191	191	191	191	191	191	191	191	340
Power Outputs >	195	195	195	195	195	195	195	195	195	195	195	195	195	276
Power Outputs >	162	162	162	162	162	162	162	162	162	162	162	162	162	384.6
Power Outputs >	315	315	315	315	315	315	315	315	315	315	315	315	315	319.9
Power Outputs >	367	367	367	367	367	367	367	367	367	367	367	367	367	387.3
Power Outputs >	313	313	313	313	313	313	313	313	313	313	313	313	313	307.6
Power Outputs >	255	255	255	255	255	255	255	255	255	255	255	255	255	429
Power Outputs >	256	256	256	256	256	256	256	256	256	256	256	256	256	439
Power Outputs >	221	221	221	221	221	221	221	221	221	221	221	221	221	440
Power Outputs >	183	183	183	183	183	183	183	183	183	183	183	183	183	462
Power Outputs >	207	207	207	207	207	207	207	207	207	207	207	207	207	456
Power Outputs >	248	248	248	248	248	248	248	248	248	248	248	248	248	468
Power Outputs >	208	208	208	208	208	208	208	208	208	208	208	208	208	990.8
Power Outputs >	255	255	255	255	255	255	255	255	255	255	255	255	255	968.3
Power Outputs >	202	202	202	202	202	202	202	202	202	202	202	202	202	1091.4
Power Outputs >	364	364	364	364	364	364	364	364	364	364	364	364	364	520
Power Outputs >	270	270	270	270	270	270	270	270	270	270	270	270	270	544.5
Power Outputs >	340	340	340	340	340	340	340	340	340	340	340	340	340	522.4
Power Outputs >	276	276	276	276	276	276	276	276	276	276	276	276	276	668.3
Power Outputs >	617	617	617	617	617	617	617	617	617	617	617	617	617	666.8
Power Outputs >	208	208	208	208	208	208	208	208	208	208	208	208	208	636.8
Power Outputs >	402	402	402	402	402	402	402	402	402	402	402	402	402	700
Power Outputs >	384.6	384.6	384.6	384.6	384.6	384.6	384.6	384.6	384.6	384.6	384.6	384.6	384.6	861
Power Outputs >	330.4	330.4	330.4	330.4	330.4	330.4	330.4	330.4	330.4	330.4	330.4	330.4	330.4	822
Power Outputs >	384.6	384.6	384.6	384.6	384.6	384.6	384.6	384.6	384.6	384.6	384.6	384.6	384.6	1023
Power Outputs >	319.9	319.9	319.9	319.9	319.9	319.9	319.9	319.9	319.9	319.9	319.9	319.9	319.9	1084
Power Outputs >	387.3	387.3	387.3	387.3	387.3	387.3	387.3	387.3	387.3	387.3	387.3	387.3	387.3	1109
Power Outputs >	307.6	307.6	307.6	307.6	307.6	307.6	307.6	307.6	307.6	307.6	307.6	307.6	307.6	1205
Power Outputs >	771	771	771	771	771	771	771	771	771	771	771	771	771	1841
Power Outputs >	488	488	488	488	488	488	488	488	488	488	488	488	488	822
Power Outputs >	1787	1787	1787	1787	1787	1787	1787	1787	1787	1787	1787	1787	1787	1306
Power Outputs >	621	621	621	621	621	621	621	621	621	621	621	621	621	1420

Power Outputs >	547	547	547	547	547	547	547	547	547	547	547	547	547	895
Power Outputs >	441	441	441	441	441	441	441	441	441	441	441	441	441	545
Power Outputs >	461	461	461	461	461	461	461	461	461	461	461	461	461	433
Power Outputs >	445	445	445	445	445	445	445	445	445	445	445	445	445	293
Power Outputs >	453	453	453	453	453	453	453	453	453	453	453	453	453	359
Power Outputs >	485	485	485	485	485	485	485	485	485	485	485	485	485	317
Power Outputs >	514	514	514	514	514	514	514	514	514	514	514	514	514	336
Power Outputs >	429	429	429	429	429	429	429	429	429	429	429	429	429	227
Power Outputs >	439	439	439	439	439	439	439	439	439	439	439	439	439	190
Power Outputs >	440	440	440	440	440	440	440	440	440	440	440	440	440	227
Power Outputs >	462	462	462	462	462	462	462	462	462	462	462	462	462	191
Power Outputs >	456	456	456	456	456	456	456	456	456	456	456	456	456	240
Power Outputs >	468	468	468	468	468	468	468	468	468	468	468	468	468	204
Power Outputs >	990.8	990.8	990.8	990.8	990.8	990.8	990.8	990.8	990.8	990.8	990.8	990.8	990.8	107
Power Outputs >	968.3	968.3	968.3	968.3	968.3	968.3	968.3	968.3	968.3	968.3	968.3	968.3	968.3	85
Power Outputs >	1091.4	1091.4	1091.4	1091.4	1091.4	1091.4	1091.4	1091.4	1091.4	1091.4	1091.4	1091.4	1091.4	112
Power Outputs >	520	520	520	520	520	520	520	520	520	520	520	520	520	97
Power Outputs >	544.5	544.5	544.5	544.5	544.5	544.5	544.5	544.5	544.5	544.5	544.5	544.5	544.5	138
Power Outputs >	522.4	522.4	522.4	522.4	522.4	522.4	522.4	522.4	522.4	522.4	522.4	522.4	522.4	110
Power Outputs >	668.3	668.3	668.3	668.3	668.3	668.3	668.3	668.3	668.3	668.3	668.3	668.3	668.3	88
Power Outputs >	666.8	666.8	666.8	666.8	666.8	666.8	666.8	666.8	666.8	666.8	666.8	666.8	666.8	111
Power Outputs >	636.8	636.8	636.8	636.8	636.8	636.8	636.8	636.8	636.8	636.8	636.8	636.8	636.8	90
Power Outputs >	700	700	700	700	700	700	700	700	700	700	700	700	700	115
Power Outputs >	861	861	861	861	861	861	861	861	861	861	861	861	861	92
Power Outputs >	822	822	822	822	822	822	822	822	822	822	822	822	822	219
Power Outputs >	1023	1023	1023	1023	1023	1023	1023	1023	1023	1023	1023	1023	1023	179
Power Outputs >	1084	1084	1084	1084	1084	1084	1084	1084	1084	1084	1084	1084	1084	223
Power Outputs >	1109	1109	1109	1109	1109	1109	1109	1109	1109	1109	1109	1109	1109	178
Power Outputs >	1205	1205	1205	1205	1205	1205	1205	1205	1205	1205	1205	1205	1205	242
Power Outputs >	1841	1841	1841	1841	1841	1841	1841	1841	1841	1841	1841	1841	1841	198
Power Outputs >	822	822	822	822	822	822	822	822	822	822	822	822	822	
Power Outputs >	1306	1306	1306	1306	1306	1306	1306	1306	1306	1306	1306	1306	1306	
Power Outputs >	1420	1420	1420	1420	1420	1420	1420	1420	1420	1420	1420	1420	1420	
Power Outputs >	895	895	895	895	895	895	895	895	895	895	895	895	895	
Power Outputs >	545	545	545	545	545	545	545	545	545	545	545	545	545	
Power Outputs >	433	433	433	433	433	433	433	433	433	433	433	433	433	
Power Outputs >	692	692	692	692	692	692	692	692	692	692	692	692	692	
Power Outputs >	1419	1419	1419	1419	1419	1419	1419	1419	1419	1419	1419	1419	1419	
Power Outputs >	1102	1102	1102	1102	1102	1102	1102	1102	1102	1102	1102	1102	1102	
Power Outputs >	1180	1180	1180	1180	1180	1180	1180	1180	1180	1180	1180	1180	1180	
Power Outputs >	485	485	485	485	485	485	485	485	485	485	485	485	485	
Power Outputs >	348	348	348	348	348	348	348	348	348	348	348	348	348	

Power Outputs >	474	474	474	474	474	474	474	474	474	474	474	474	474	
Power Outputs >	1560	1560	1560	1560	1560	1560	1560	1560	1560	1560	1560	1560	1560	
Power Outputs >	735	735	735	735	735	735	735	735	735	735	735	735	735	
Power Outputs >	545	545	545	545	545	545	545	545	545	545	545	545	545	
Power Outputs >	600	1294	1294	1294	1294	1294	1294	1294	1294	1294	1294	1294	769	
Power Outputs >	488	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	545	
Power Outputs >	508	769	769	769	769	769	769	769	769	769	769	769	600	
Power Outputs >	233	545	545	545	545	545	545	545	545	545	545	545	488	
Power Outputs >	1260	600	1337	1337	1337	1337	1337	1337	1337	1337	1337	1337	508	
Power Outputs >	940	488	600	600	600	600	600	600	600	600	600	600	233	
Power Outputs >	530	508	488	488	488	488	488	488	488	488	488	488	1260	
Power Outputs >	921	233	508	508	508	508	508	508	508	508	508	508	940	
Power Outputs >	488	1260	233	233	233	233	233	233	233	233	233	233	530	
Power Outputs >	206	940	1260	1260	1260	1260	1260	1260	1260	1260	1260	1260	921	
Power Outputs >	667	530	940	940	940	940	940	940	940	940	940	940	488	
Power Outputs >	193	921	530	530	530	530	530	530	530	530	530	530	206	
Power Outputs >	114	488	921	921	921	921	921	921	921	921	921	921	667	
Power Outputs >	243	206	488	488	488	488	488	488	488	488	488	488	193	
Power Outputs >	144	667	206	206	206	206	206	206	206	206	206	206	114	
Power Outputs >	5	193	667	667	667	667	667	667	667	667	667	667	243	
Power Outputs >	7	114	193	193	193	193	193	193	193	193	193	193	144	
Power Outputs >	53	243	114	114	114	114	114	114	114	114	114	114	5	
Power Outputs >	127	144	243	243	243	243	243	243	243	243	243	243	7	
Power Outputs >	106	5	144	144	144	144	144	144	144	144	144	144	53	
Power Outputs >	138	7	5	5	5	5	5	5	5	5	5	5	6	
Power Outputs >	115	53	7	7	7	7	7	7	7	7	7	7	5	
Power Outputs >	144	127	53	53	53	53	53	53	53	53	53	53	127	
Power Outputs >	118	106	6	6	6	6	6	6	6	6	6	6	106	
Power Outputs >	196	138	5	5	5	5	5	5	5	5	5	5	138	
Power Outputs >	162	115	127	127	127	127	127	127	127	127	127	127	115	
Power Outputs >	214	144	106	106	106	106	106	106	106	106	106	106	144	
Power Outputs >	170	118	138	138	138	138	138	138	138	138	138	138	118	
Power Outputs >	168	142	115	115	115	115	115	115	115	115	115	115	142	
Power Outputs >	141	121	144	144	144	144	144	144	144	144	144	144	121	
Power Outputs >	227	116	118	118	118	118	118	118	118	118	118	118	116	
Power Outputs >	190	138	142	142	142	142	142	142	142	142	142	142	138	
Power Outputs >	227	150	121	121	121	121	121	121	121	121	121	121	196	
Power Outputs >	191	124	116	116	116	116	116	116	116	116	116	116	162	
Power Outputs >	107	196	138	138	138	138	138	138	138	138	138	138	214	
Power Outputs >	85	162	150	150	150	150	150	150	150	150	150	150	170	
Power Outputs >	112	214	124	124	124	124	124	124	124	124	124	124	168	
Power Outputs >	97	170	196	196	196	196	196	196	196	196	196	196	141	

Power Outputs >	449	168	162	162	162	162	162	162	162	162	162	162	189	
Power Outputs >	169	141	214	214	214	214	214	214	214	214	214	214	150	
Power Outputs >	117	189	170	170	170	170	170	170	170	170	170	170	170	
Power Outputs >	456	150	168	168	168	168	168	168	168	168	168	168	142	
Power Outputs >	138	170	141	141	141	141	141	141	141	141	141	141	293	
Power Outputs >	119	142	189	189	189	189	189	189	189	189	189	189	359	
Power Outputs >	94	293	150	150	150	150	150	150	150	150	150	150	317	
Power Outputs >	134	359	170	170	170	170	170	170	170	170	170	170	336	
Power Outputs >	110	317	142	142	142	142	142	142	142	142	142	142	1203	
Power Outputs >	169	336	102	102	102	102	102	102	102	102	102	102	476	
Power Outputs >	571	1203	85	85	85	85	85	85	85	85	85	85	95	
Power Outputs >	204	476	293	293	293	293	293	293	293	293	293	293	227	
Power Outputs >	140	95	359	359	359	359	359	359	359	359	359	359	190	
Power Outputs >	110	227	317	317	317	317	317	317	317	317	317	317	227	
Power Outputs >	87	190	336	336	336	336	336	336	336	336	336	336	191	
Power Outputs >	138	227	1203	1203	1203	1203	1203	1203	1203	1203	1203	1203	240	
Power Outputs >	110	191	476	476	476	476	476	476	476	476	476	476	204	
Power Outputs >	88	240	95	95	95	95	95	95	95	95	95	95	229	
Power Outputs >	143	204	227	227	227	227	227	227	227	227	227	227	193	
Power Outputs >	112	229	190	190	190	190	190	190	190	190	190	190	230	
Power Outputs >	140	193	227	227	227	227	227	227	227	227	227	227	193	
Power Outputs >	999	107	191	191	191	191	191	191	191	191	191	191	107	
Power Outputs >	370	85	240	240	240	240	240	240	240	240	240	240	85	
Power Outputs >	129	112	204	204	204	204	204	204	204	204	204	204	112	
Power Outputs >	89	97	229	229	229	229	229	229	229	229	229	229	97	
Power Outputs >	89	122	193	193	193	193	193	193	193	193	193	193	122	
Power Outputs >	110	102	230	230	230	230	230	230	230	230	230	230	102	
Power Outputs >	176	113	193	193	193	193	193	193	193	193	193	193	113	
Power Outputs >	109	97	229	229	229	229	229	229	229	229	229	229	97	
Power Outputs >	111	449	192	192	192	192	192	192	192	192	192	192	115	
Power Outputs >	131	169	107	107	107	107	107	107	107	107	107	107	92	
Power Outputs >	90	117	85	85	85	85	85	85	85	85	85	85	449	
Power Outputs >	201	456	112	112	112	112	112	112	112	112	112	112	169	
Power Outputs >	219	138	97	97	97	97	97	97	97	97	97	97	117	
Power Outputs >	179	119	122	122	122	122	122	122	122	122	122	122	456	
Power Outputs >	223	94	102	102	102	102	102	102	102	102	102	102	138	
Power Outputs >	178	134	113	113	113	113	113	113	113	113	113	113	119	
Power Outputs >	203	110	97	97	97	97	97	97	97	97	97	97	94	
Power Outputs >	262	169	115	115	115	115	115	115	115	115	115	115	134	
Power Outputs >	279	152	92	92	92	92	92	92	92	92	92	92	110	
Power Outputs >	208	114	119	119	119	119	119	119	119	119	119	119	169	
Power Outputs >	283	134	98	98	98	98	98	98	98	98	98	98	152	

Power Outputs >	283	103	449	449	449	449	449	449	449	449	449	449	114	
Power Outputs >	224	689	169	169	169	169	169	169	169	169	169	169	689	
Power Outputs >	313	270	117	117	117	117	117	117	117	117	117	117	270	
Power Outputs >	1325	177	456	456	456	456	456	456	456	456	456	456	177	
Power Outputs >	467	571	138	138	138	138	138	138	138	138	138	138	571	
Power Outputs >	235	204	119	119	119	119	119	119	119	119	119	119	204	
Power Outputs >	174	140	94	94	94	94	94	94	94	94	94	94	140	
Power Outputs >	224	110	134	134	134	134	134	134	134	134	134	134	110	
Power Outputs >	174	87	110	110	110	110	110	110	110	110	110	110	87	
Power Outputs >	289	138	169	169	169	169	169	169	169	169	169	169	138	
Power Outputs >	942	110	152	152	152	152	152	152	152	152	152	152	110	
Power Outputs >	274	88	114	114	114	114	114	114	114	114	114	114	88	
Power Outputs >	268	143	134	134	134	134	134	134	134	134	134	134	143	
Power Outputs >	308	112	103	103	103	103	103	103	103	103	103	103	112	
Power Outputs >	286	140	139	139	139	139	139	139	139	139	139	139	140	
Power Outputs >	646	999	96	96	96	96	96	96	96	96	96	96	999	
Power Outputs >	484	370	148	148	148	148	148	148	148	148	148	689	370	
Power Outputs >	348	129	112	112	112	112	112	112	112	112	112	270	129	
Power Outputs >	470	89	689	689	689	689	689	689	689	689	689	177	89	
Power Outputs >	371	89	270	270	270	270	270	270	270	270	270	571	89	
Power Outputs >	300	110	177	177	177	177	177	177	177	177	177	204	110	
Power Outputs >	993	176	571	571	571	571	571	571	571	571	571	140	176	
Power Outputs >	525	109	204	204	204	204	204	204	204	204	204	110	109	
Power Outputs >	209	111	140	140	140	140	140	140	140	140	140	87	111	
Power Outputs >	233	131	110	110	110	110	110	110	110	110	110	138	131	
Power Outputs >	254	90	87	87	87	87	87	87	87	87	87	110	90	
Power Outputs >		201	138	138	138	138	138	138	138	138	138	88	201	
Power Outputs >		133	110	110	110	110	110	110	110	110	110	143	133	
Power Outputs >		111	88	88	88	88	88	88	88	88	88	112	111	
Power Outputs >		115	143	143	143	143	143	143	143	143	143	140	115	
Power Outputs >		92	112	112	112	112	112	112	112	112	112	999	92	
Power Outputs >		135	140	140	140	140	140	140	140	140	140	370	117	
Power Outputs >		114	999	999	999	999	999	999	999	999	999	129	94	
Power Outputs >		117	370	370	370	370	370	370	370	370	370	89	219	
Power Outputs >		94	129	129	129	129	129	129	129	129	129	89	179	
Power Outputs >		219	89	89	89	89	89	89	89	89	89	110	223	
Power Outputs >		179	89	89	89	89	89	89	89	89	89	176	178	
Power Outputs >		223	110	110	110	110	110	110	110	110	110	109	203	
Power Outputs >		178	176	176	176	176	176	176	176	176	176	111	242	
Power Outputs >		203	109	109	109	109	109	109	109	109	109	131	198	
Power Outputs >		242	111	111	111	111	111	111	111	111	111	90	225	
Power Outputs >		198	131	131	131	131	131	131	131	131	131	201	180	

Power Outputs >		225	90	90	90	90	90	90	90	90	90	133	232	
Power Outputs >		180	201	201	201	201	201	201	201	201	201	111	190	
Power Outputs >		262	133	133	133	133	133	133	133	133	133	115	262	
Power Outputs >		279	111	111	111	111	111	111	111	111	111	92	279	
Power Outputs >		208	115	115	115	115	115	115	115	115	115	135	208	
Power Outputs >		283	92	92	92	92	92	92	92	92	92	114	283	
Power Outputs >		283	135	135	135	135	135	135	135	135	135	117	283	
Power Outputs >		224	114	114	114	114	114	114	114	114	114	94	224	
Power Outputs >		313	117	117	117	117	117	117	117	117	117	138	313	
Power Outputs >		286	94	94	94	94	94	94	94	94	94	115	286	
Power Outputs >		233	138	138	138	138	138	138	138	138	138	118	233	
Power Outputs >		294	115	115	115	115	115	115	115	115	115	96	1325	
Power Outputs >		240	118	118	118	118	118	118	118	118	118	219	467	
Power Outputs >		1325	96	96	96	96	96	96	96	96	96	179	235	
Power Outputs >		467	140	140	140	140	140	140	140	140	140	223	174	
Power Outputs >		235	117	117	117	117	117	117	117	117	117	178	224	
Power Outputs >		174	121	121	121	121	121	121	121	121	121	203	174	
Power Outputs >		224	97	97	97	97	97	97	97	97	97	242	289	
Power Outputs >		174	219	219	219	219	219	219	219	219	219	198	228	
Power Outputs >		289	179	179	179	179	179	179	179	179	179	225	173	
Power Outputs >		228	223	223	223	223	223	223	223	223	223	180	942	
Power Outputs >		173	178	178	178	178	178	178	178	178	178	232	274	
Power Outputs >		236	203	203	203	203	203	203	203	203	203	190	268	
Power Outputs >		179	242	242	242	242	242	242	242	242	242	234	308	
Power Outputs >		942	198	198	198	198	198	198	198	198	198	188	286	
Power Outputs >		274	225	225	225	225	225	225	225	225	225	262	646	
Power Outputs >		268	180	180	180	180	180	180	180	180	180	279	484	
Power Outputs >		308	232	232	232	232	232	232	232	232	232	208	348	
Power Outputs >		286	190	190	190	190	190	190	190	190	190	283	470	
Power Outputs >		169	234	234	234	234	234	234	234	234	234	283	371	
Power Outputs >		646	188	188	188	188	188	188	188	188	188	224	300	
Power Outputs >		484	262	262	262	262	262	262	262	262	262	313	499	
Power Outputs >		348	279	279	279	279	279	279	279	279	279	286	392	
Power Outputs >		470	208	208	208	208	208	208	208	208	208	233	993	
Power Outputs >		371	283	283	283	283	283	283	283	283	283	294	525	
Power Outputs >		300	283	283	283	283	283	283	283	283	283	240	209	
Power Outputs >		499	224	224	224	224	224	224	224	224	224	291	233	
Power Outputs >		392	313	313	313	313	313	313	313	313	313	233	254	
Power Outputs >		519	286	286	286	286	286	286	286	286	286	1325	210	
Power Outputs >		399	233	233	233	233	233	233	233	233	233	467		
Power Outputs >		993	294	294	294	294	294	294	294	294	294	235		
Power Outputs >		525	240	240	240	240	240	240	240	240	240	174		

Power Outputs >		209	291	291	291	291	291	291	291	291	291	224		
Power Outputs >		233	233	233	233	233	233	233	233	233	233	174		
Power Outputs >		254	285	285	285	285	285	285	285	285	285	289		
Power Outputs >		210	228	228	228	228	228	228	228	228	228	228		
Power Outputs >		238	1325	1325	1325	1325	1325	1325	1325	1325	1325	173		
Power Outputs >			467	467	467	467	467	467	467	467	467	236		
Power Outputs >			235	235	235	235	235	235	235	235	235	179		
Power Outputs >			174	174	174	174	174	174	174	174	174	268		
Power Outputs >			224	224	224	224	224	224	224	224	224	198		
Power Outputs >			174	174	174	174	174	174	174	174	174	942		
Power Outputs >			289	289	289	289	289	289	289	289	289	274		
Power Outputs >			228	228	228	228	228	228	228	228	228	268		
Power Outputs >			173	173	173	173	173	173	173	173	173	308		
Power Outputs >			236	236	236	236	236	236	236	236	236	286		
Power Outputs >			179	179	179	179	179	179	179	179	179	169		
Power Outputs >			268	268	268	268	268	268	268	268	268	646		
Power Outputs >			198	198	198	198	198	198	198	198	198	484		
Power Outputs >			261	261	261	261	261	261	261	261	261	348		
Power Outputs >			208	208	208	208	208	208	208	208	208	470		
Power Outputs >			942	942	942	942	942	942	942	942	942	371		
Power Outputs >			274	274	274	274	274	274	274	274	274	300		
Power Outputs >			268	268	268	268	268	268	268	268	268	499		
Power Outputs >			308	308	308	308	308	308	308	308	308	392		
Power Outputs >			286	286	286	286	286	286	286	286	286	519		
Power Outputs >			169	169	169	169	169	169	169	169	169	399		
Power Outputs >			193	193	193	193	193	193	193	193	193	495		
Power Outputs >			150	150	150	150	150	150	150	150	150	398		
Power Outputs >			646	646	646	646	646	646	646	646	646	993		
Power Outputs >			484	484	484	484	484	484	484	484	484	525		
Power Outputs >			348	348	348	348	348	348	348	348	348	209		
Power Outputs >			470	470	470	470	470	470	470	470	470	233		
Power Outputs >			371	371	371	371	371	371	371	371	371	254		
Power Outputs >			300	300	300	300	300	300	300	300	300	210		
Power Outputs >			499	499	499	499	499	499	499	499	499	238		
Power Outputs >			392	392	392	392	392	392	392	392	392	270		
Power Outputs >			519	519	519	519	519	519	519	519	519			
Power Outputs >			399	399	399	399	399	399	399	399	399			
Power Outputs >			495	495	495	495	495	495	495	495	495			
Power Outputs >			398	398	398	398	398	398	398	398	398			
Power Outputs >			453	453	453	453	453	453	453	453	453			
Power Outputs >			369	369	369	369	369	369	369	369	369			
Power Outputs >			993	993	993	993	993	993	993	993	993			

Power Outputs >			525	525	525	525	525	525	525	525	525			
Power Outputs >			209	209	209	209	209	209	209	209	209			
Power Outputs >			233	233	233	233	233	233	233	233	233			
Power Outputs >			254	254	254	254	254	254	254	254	254			
Power Outputs >			210	210	210	210	210	210	210	210	210			
Power Outputs >			238	238	238	238	238	238	238	238	238			
Power Outputs >			270	270	270	270	270	270	270	270	270			
Power Outputs >			256	256	256	256	256	256	256	256	256			
Average power transmitted (Pt)	405.2	373.1	349.5	349.5	349.5	349.5	349.5	349.5	349.5	349.5	349.5	356.8	367.5	446.9

Frequency >	1.71	1.715	1.72	1.725	1.73	1.735	1.74	1.745	1.75	1.755	1.76	1.765	1.77	1.775	1.78
Power Outputs >	24	24	24	24	24	24	24	24	24	24	209	209	209	209	209
Power Outputs >	209	209	209	209	209	209	209	209	209	209	174	174	174	174	174
Power Outputs >	174	174	174	174	174	174	174	174	174	174	178	178	178	178	178
Power Outputs >	178	178	178	178	178	178	178	178	178	178	150	150	150	150	145
Power Outputs >	150	150	150	150	150	150	150	150	150	150	145	145	145	145	126
Power Outputs >	145	145	145	145	145	145	145	145	145	145	126	126	126	126	220
Power Outputs >	126	126	126	126	126	126	126	126	126	126	145	145	145	145	194
Power Outputs >	145	145	145	145	145	145	145	145	145	145	126	126	126	126	210
Power Outputs >	126	126	126	126	126	126	126	126	126	126	357	357	357	357	183
Power Outputs >	357	357	357	357	357	357	357	357	357	357	225	225	225	225	106
Power Outputs >	225	225	225	225	225	225	225	225	225	225	187	187	187	187	155
Power Outputs >	187	187	187	187	187	187	187	187	187	187	232	232	232	232	126
Power Outputs >	232	232	232	232	232	232	232	232	232	232	197	197	197	197	123
Power Outputs >	197	197	197	197	197	197	197	197	197	197	181	181	181	181	107
Power Outputs >	181	181	181	181	181	181	181	181	181	181	261	261	261	261	157
Power Outputs >	261	261	261	261	261	261	261	261	261	261	203	203	203	203	109
Power Outputs >	203	203	203	203	203	203	203	203	203	203	262	262	262	262	130
Power Outputs >	262	262	262	262	262	262	262	262	262	262	206	206	206	206	128
Power Outputs >	206	206	206	206	206	206	206	206	206	206	216	216	216	216	184
Power Outputs >	216	216	216	216	216	216	216	216	216	216	249	249	249	249	147
Power Outputs >	249	249	249	249	249	249	249	249	249	249	228	228	228	228	193
Power Outputs >	228	228	228	228	228	228	228	228	228	228	183.2	183.2	183.2	183.2	156
Power Outputs >	183.2	183.2	183.2	183.2	183.2	183.2	183.2	183.2	183.2	183.2	248.9	248.9	248.9	248.9	
Power Outputs >	248.9	248.9	248.9	248.9	248.9	248.9	248.9	248.9	248.9	248.9	197.7	197.7	197.7	197.7	
Power Outputs >	197.7	197.7	197.7	197.7	197.7	197.7	197.7	197.7	197.7	197.7	292	292	292	292	
Power Outputs >	292	292	292	292	292	292	292	292	292	292	220	220	220	220	
Power Outputs >	421	421	421	421	421	421	421	421	421	421	194	194	194	194	
Power Outputs >	424	424	424	424	424	424	424	424	424	424	210	210	210	210	
Power Outputs >	297	297	297	297	297	297	297	297	297	297	183	183	183	183	
Power Outputs >	316	316	316	316	316	316	316	316	316	316	106	106	106	106	
Power Outputs >	325	325	325	325	325	325	325	325	325	325	155	155	155	155	
Power Outputs >	329	329	329	329	329	329	329	329	329	329	126	126	126	126	
Power Outputs >	345	345	345	345	345	345	345	345	345	345	123	123	123	123	
Power Outputs >	333	333	333	333	333	333	333	333	333	333	107	107	107	107	
Power Outputs >	922.6	922.6	922.6	922.6	922.6	922.6	922.6	922.6	922.6	922.6	157	157	157	157	
Power Outputs >	736.2	736.2	736.2	736.2	736.2	736.2	736.2	736.2	736.2	736.2	109	109	109	109	
Power Outputs >	404.6	404.6	404.6	404.6	404.6	404.6	404.6	404.6	404.6	404.6	130	130	130	130	
Power Outputs >	460.3	460.3	460.3	460.3	460.3	460.3	460.3	460.3	460.3	460.3	128	128	128	128	
Power Outputs >	437.5	437.5	437.5	437.5	437.5	437.5	437.5	437.5	437.5	437.5	111	111	111	111	
Power Outputs >	449.8	449.8	449.8	449.8	449.8	449.8	449.8	449.8	449.8	449.8	138	138	138	138	
Power Outputs >	588	588	588	588	588	588	588	588	588	588	134	134	134	134	
Power Outputs >	439	439	439	439	439	439	439	439	439	439	129	129	129	129	

Power Outputs >	538	538	538	538	538	538	538	538	538	538	143	143	143	143	
Power Outputs >	428	428	428	428	428	428	428	428	428	428	140	140	140	140	
Power Outputs >	480	480	480	480	480	480	480	480	480	480	131	131	131	184	
Power Outputs >	538	538	538	538	538	538	538	538	538	538	146	146	146	147	
Power Outputs >	546	546	546	546	546	546	546	546	546	546	143	143	143	193	
Power Outputs >	465	465	465	465	465	465	465	465	465	465	184	184	184	156	
Power Outputs >	703	703	703	703	703	703	703	703	703	703	147	147	147	212	
Power Outputs >	559	559	559	559	559	559	559	559	559	559	193	193	193	171	
Power Outputs >	389	389	389	389	389	389	389	389	389	389	156	156	156	197	
Power Outputs >	611	611	611	611	611	611	611	611	611	611	212	212	212	159	
Power Outputs >	475	475	475	475	475	475	475	475	475	475	171	171	171	205	
Power Outputs >	118	789	789	789	789	789	789	789	789	118	197	197	197	155	
Power Outputs >	157	627	627	627	627	627	627	627	627	157	159	159	159		
Power Outputs >	161	826	826	826	826	826	826	826	826	161	205	205	205		
Power Outputs >	136	656	656	656	656	656	656	656	656	136	155	155	155		
Power Outputs >	168	118	771	771	771	771	771	771	118	168	230	230	230		
Power Outputs >	144	157	585	585	585	585	585	585	157	144	186	186	186		
Power Outputs >	130	161	118	118	118	118	118	118	161	130					
Power Outputs >	106	136	95	95	95	95	95	95	136	106					
Power Outputs >	125	168	118	118	118	118	118	118	168	125					
Power Outputs >	103	144	157	157	157	157	157	157	144	103					
Power Outputs >	220	180	161	161	161	161	161	161	180	137					
Power Outputs >	194	156	136	136	136	136	136	136	156	112					
Power Outputs >	210	153	168	168	168	168	168	168	153	220					
Power Outputs >	183	136	144	144	144	144	144	144	136	194					
Power Outputs >	98	130	180	180	180	180	180	180	130	210					
Power Outputs >	379	106	156	156	156	156	156	156	106	183					
Power Outputs >	318	125	153	153	153	153	153	153	125	53					
Power Outputs >	53	103	136	136	136	136	136	136	103	43					
Power Outputs >	43	137	125	125	125	125	125	125	137	61					
Power Outputs >	61	112	151	151	151	151	151	151	112	51					
Power Outputs >	51	117	130	130	130	130	130	130	117	63					
Power Outputs >	155	99	106	106	106	106	106	106	99	54					
Power Outputs >	114	220	125	125	125	125	125	125	112	66					
Power Outputs >	106	194	103	103	103	103	103	103	94	56					
Power Outputs >	136	210	137	137	137	137	137	137	220	155					
Power Outputs >	151	183	112	112	112	112	112	112	194	114					
Power Outputs >	113	98	117	117	117	117	117	117	210	106					
Power Outputs >	168	379	99	99	99	99	99	99	183	136					
Power Outputs >	125	318	112	112	112	112	112	112	98	161					
Power Outputs >	176	395	94	94	94	94	94	94	379	135					
Power Outputs >	141	332	86	86	86	86	86	86	318	151					

Power Outputs >	110	420	69	69	69	69	69	69	395	113					
Power Outputs >	106	355	220	220	220	220	220	220	332	168					
Power Outputs >	155	400	194	194	194	194	194	194	420	125					
Power Outputs >	126	337	210	210	210	210	210	210	355	155					
Power Outputs >	123	53	183	183	183	183	183	183	400	124					
Power Outputs >	176	43	98	98	98	98	98	98	337	106					
Power Outputs >	140	61	379	379	379	379	379	379	449	155					
Power Outputs >	112	51	318	318	318	318	318	318	370	126					
Power Outputs >	107	63	395	395	395	395	395	395	419	123					
Power Outputs >	157	54	332	332	332	332	332	332	383	107					
Power Outputs >	100	66	420	420	420	420	420	420	53	157					
Power Outputs >	87	56	355	355	355	355	355	355	43	140					
Power Outputs >	104	155	400	400	400	400	400	400	61	176					
Power Outputs >	89	114	337	337	337	337	337	337	51	112					
Power Outputs >	202	106	449	449	449	449	449	449	63	109					
Power Outputs >	184	136	370	370	370	370	370	370	54	130					
Power Outputs >	147	161	419	419	419	419	419	419	66	128					
Power Outputs >	193	135	383	383	383	383	383	383	56	111					
Power Outputs >	156	146	53	53	53	53	53	53	55	138					
Power Outputs >	291	118	43	43	43	43	43	43	44	134					
Power Outputs >	155	151	61	61	61	61	61	61	59	129					
Power Outputs >	307	113	51	51	51	51	51	51	48	143					
Power Outputs >	275	168	63	63	63	63	63	63	155	140					
Power Outputs >	279	125	54	54	54	54	54	54	114	131					
Power Outputs >	224	155	66	66	66	66	66	66	106	146					
Power Outputs >	256	124	56	56	56	56	56	56	136	143					
Power Outputs >	220	161	55	55	55	55	55	55	161	100					
Power Outputs >	256	125	44	44	44	44	44	44	135	87					
Power Outputs >	196	176	59	59	59	59	59	59	146	104					
Power Outputs >	471	141	48	48	48	48	48	48	118	89					
Power Outputs >	449	110	155	155	155	155	155	155	143	202					
Power Outputs >	340	106	114	114	114	114	114	114	116	106					
Power Outputs >	243	155	106	106	106	106	106	106	151	91					
Power Outputs >	221	126	136	136	136	136	136	136	113	184					
Power Outputs >		123	161	161	161	161	161	161	168	147					
Power Outputs >		176	135	135	135	135	135	135	125	193					
Power Outputs >		140	146	146	146	146	146	146	155	156					
Power Outputs >		112	118	118	118	118	118	118	124	212					
Power Outputs >		107	143	143	143	143	143	143	161	171					
Power Outputs >		157	116	116	116	116	116	116	125	197					
Power Outputs >		140	156	156	156	156	156	156	157	159					
Power Outputs >		176	133	133	133	133	133	133	125	205					

Power Outputs >		112	151	151	151	151	151	151	176	155					
Power Outputs >		109	113	113	113	113	113	113	141	230					
Power Outputs >		130	168	168	168	168	168	168	110	186					
Power Outputs >		128	125	125	125	125	125	125	106	291					
Power Outputs >		177	155	155	155	155	155	155	155	155					
Power Outputs >		140	124	124	124	124	124	124	126	307					
Power Outputs >		111	161	161	161	161	161	161	123	275					
Power Outputs >		111	125	125	125	125	125	125	176	320					
Power Outputs >		138	157	157	157	157	157	157	140	281					
Power Outputs >		134	125	125	125	125	125	125	112	279					
Power Outputs >		100	168	168	168	168	168	168	107	224					
Power Outputs >		87	133	133	133	133	133	133	157	256					
Power Outputs >		104	176	176	176	176	176	176	140	220					
Power Outputs >		89	141	141	141	141	141	141	176	257					
Power Outputs >		202	110	110	110	110	110	110	112	219					
Power Outputs >		106	106	106	106	106	106	106	109	256					
Power Outputs >		91	155	155	155	155	155	155	130	270					
Power Outputs >		109	126	126	126	126	126	126	128	196					
Power Outputs >		93	123	123	123	123	123	123	177	471					
Power Outputs >		184	176	176	176	176	176	176	140	449					
Power Outputs >		147	140	140	140	140	140	140	111	340					
Power Outputs >		193	112	112	112	112	112	112	111	409					
Power Outputs >		156	107	107	107	107	107	107	138	359					
Power Outputs >		212	157	157	157	157	157	157	134	243					
Power Outputs >		171	140	140	140	140	140	140	177	221					
Power Outputs >		197	176	176	176	176	176	176	139	258					
Power Outputs >		159	112	112	112	112	112	112	109	245					
Power Outputs >		291	109	109	109	109	109	109	129						
Power Outputs >		155	130	130	130	130	130	130	143						
Power Outputs >		307	128	128	128	128	128	128	140						
Power Outputs >		275	177	177	177	177	177	177	131						
Power Outputs >		320	140	140	140	140	140	140	146						
Power Outputs >		281	111	111	111	111	111	111	143						
Power Outputs >		302	111	111	111	111	111	111	100						
Power Outputs >		272	138	138	138	138	138	138	87						
Power Outputs >		279	134	134	134	134	134	134	104						
Power Outputs >		224	177	177	177	177	177	177	89						
Power Outputs >		256	139	139	139	139	139	139	202						
Power Outputs >		220	109	109	109	109	109	109	106						
Power Outputs >		257	129	129	129	129	129	129	91						
Power Outputs >		219	143	143	143	143	143	143	109						
Power Outputs >		271	140	140	140	140	140	140	93						

Power Outputs >		227	111	111	111	111	111	111	94						
Power Outputs >		256	131	131	131	131	131	131	112						
Power Outputs >		270	176	176	176	176	176	176	184						
Power Outputs >		187	140	140	140	140	140	140	147						
Power Outputs >		196	146	146	146	146	146	146	193						
Power Outputs >		471	143	143	143	143	143	143	156						
Power Outputs >		449	100	100	100	100	100	100	212						
Power Outputs >		340	87	87	87	87	87	87	171						
Power Outputs >		409	104	104	104	104	104	104	197						
Power Outputs >		359	89	89	89	89	89	89	159						
Power Outputs >		441	202	202	202	202	202	202	205						
Power Outputs >		337	106	106	106	106	106	106	155						
Power Outputs >		243	91	91	91	91	91	91	230						
Power Outputs >		221	109	109	109	109	109	109	186						
Power Outputs >		258	93	93	93	93	93	93	291						
Power Outputs >		245	94	94	94	94	94	94	155						
Power Outputs >			112	112	112	112	112	112	307						
Power Outputs >			114	114	114	114	114	114	275						
Power Outputs >			95	95	95	95	95	95	320						
Power Outputs >			184	184	184	184	184	184	281						
Power Outputs >			147	147	147	147	147	147	302						
Power Outputs >			193	193	193	193	193	193	272						
Power Outputs >			156	156	156	156	156	156	305						
Power Outputs >			212	212	212	212	212	212	269						
Power Outputs >			171	171	171	171	171	171	279						
Power Outputs >			197	197	197	197	197	197	224						
Power Outputs >			159	159	159	159	159	159	256						
Power Outputs >			205	205	205	205	205	205	220						
Power Outputs >			155	155	155	155	155	155	257						
Power Outputs >			230	230	230	230	230	230	219						
Power Outputs >			186	186	186	186	186	186	271						
Power Outputs >			291	291	291	291	291	291	227						
Power Outputs >			155	155	155	155	155	155	272						
Power Outputs >			307	307	307	307	307	307	230						
Power Outputs >			275	275	275	275	275	275	256						
Power Outputs >			320	320	320	320	320	320	270						
Power Outputs >			281	281	281	281	281	281	187						
Power Outputs >			302	302	302	302	302	302	196						
Power Outputs >			272	272	272	272	272	272	471						
Power Outputs >			305	305	305	305	305	305	449						
Power Outputs >			269	269	269	269	269	269	340						
Power Outputs >			303	303	303	303	303	303	409						

Power Outputs >			256	256	256	256	256	256	359						
Power Outputs >			279	279	279	279	279	279	441						
Power Outputs >			224	224	224	224	224	224	337						
Power Outputs >			256	256	256	256	256	256	393						
Power Outputs >			220	220	220	220	220	220	313						
Power Outputs >			257	257	257	257	257	257	243						
Power Outputs >			219	219	219	219	219	219	221						
Power Outputs >			271	271	271	271	271	271	258						
Power Outputs >			227	227	227	227	227	227	245						
Power Outputs >			272	272	272	272	272	272	250						
Power Outputs >			230	230	230	230	230	230	253						
Power Outputs >			246	246	246	246	246	246							
Power Outputs >			222	222	222	222	222	222							
Power Outputs >			256	256	256	256	256	256							
Power Outputs >			270	270	270	270	270	270							
Power Outputs >			187	187	187	187	187	187							
Power Outputs >			259	259	259	259	259	259							
Power Outputs >			177	177	177	177	177	177							
Power Outputs >			196	196	196	196	196	196							
Power Outputs >			471	471	471	471	471	471							
Power Outputs >			449	449	449	449	449	449							
Power Outputs >			340	340	340	340	340	340							
Power Outputs >			409	409	409	409	409	409							
Power Outputs >			359	359	359	359	359	359							
Power Outputs >			441	441	441	441	441	441							
Power Outputs >			337	337	337	337	337	337							
Power Outputs >			393	393	393	393	393	393							
Power Outputs >			313	313	313	313	313	313							
Power Outputs >			330	330	330	330	330	330							
Power Outputs >			259	259	259	259	259	259							
Power Outputs >			243	243	243	243	243	243							
Power Outputs >			221	221	221	221	221	221							
Power Outputs >			258	258	258	258	258	258							
Power Outputs >			245	245	245	245	245	245							
Power Outputs >			250	250	250	250	250	250							
Power Outputs >			253	253	253	253	253	253							
Average power transmitted (Pt)	247.6	240.3	230.1	230.1	230.1	230.1	230.1	230.1	232.2	228.7	175.6	175.6	175.6	176.4	150.5

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