WHY ARE PORTABLE TWO-WAY RADIOS LARGER THAN CELLPHONES?

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INTRODUCTION

Very interesting questions that are often asked are "Why are two-way radios so BIG?" and "Why can't two-way radios be made as small as cellphones?" This paper will address these questions and more.

While two-way radio devices allow for voice communications just like mobile cellphones, they are very different than mobile cellphones on many levels. There is a natural tendency to compare two-way radio to cellphones because of how prevalent cellphones have become to the general public globally. This paper will highlight the differences so that you can appreciate the use, utility, and design of two-way radios.

THE DIFFERENCES

One fundamental difference between cellphones and two-way radios is who uses two-way radio. Two-way radios are used by professionals in the industrial and government areas of society, whereas cellphones are used mostly by consumers. Two-way radios are considered inputs of production, where the use of two-way radio are required as part of the tools-of-the-trade in industry and government to perform their mission or in the production of goods and/or services. Cellphones are one-to-one communication devices, whereas two-way radios are one-to-many communication devices. Cellphones are used for individual calls, whereas two-way radios are used primarily as a communications tool for the organization.

Because two-way radio is an input to the production process or part of the value chain, most industrial or government users will buy the entire two-way radio system and use it internally as a tool, very much like how they procure computers, vehicles, and uniforms for their employees. Because they must procure the two-way radio system as a capital cost to their business, the industrial and government organizations will attempt to minimize or optimize the cost of the system while still meeting their technical and operational requirements. One way to achieve lower two-way radio system costs is to minimize the number of sites inside a two-way radio infrastructure. Typical infrastructure power output for high power two-way radio systems are around 25-100W. In fact, one of the design philosophies of two-way radio technology is to maximize the coverage area so that as many two-way radios can be communicated with within a given site. This philosophy results in a minimizing of the number of sites.

As a consequence of the high-power radio transmitters, the two-way subscriber radio – the portable – must operate with a much higher power level in order for it to talk back into the infrastructure (talk-in).

Typical power levels are about 1-5W. In contrast, cellphones are typically 0.6W. Because the cell sizes are larger for two-way radio systems, the talk-in range of the portable radio must be compensated with higher power output…up to a point.

Compared to cellular, cellular networks benefit from smaller cell sizes. A smaller cell size gives cellular systems more capacity. More capacity means more cellular call handling capability, and therefore more revenue. Contrary to cellular design philosophy, two-way radio systems benefit more from larger cell sizes - the larger the two-way radio cell, the better, because a larger two-way radio cell size is able to capture more portable radios to talk to.

Is it possible to operate the two-way radio system at lower power levels, thereby shrinking the radio size? The answer is yes, it's very possible and it has been done. But the tradeoff for a smaller radio size is a larger number of infrastructure sites. Ultimately, this kind of tradeoff impacts the initial capital acquisition costs of the system (higher due to more sites) and the longer-term operating & maintenance costs of the system over the life of the system (higher due to more sites). While the user of the portable radio may see a smaller portable device, the system owner may pay a significantly higher amount of money for the infrastructure. Indeed, for the system owner it becomes a fine balance between making the end-users happy with the right size portable device that meets the technical & operational requirements vs. the overall capital and the on-going operational & maintenance costs of the system.

An interesting consequence of a higher power output level is that it also increases the reliability of a feature found in two-way radio that is not available in cellular – direct mode operation or repeater talk-around. Two-way radio systems have this feature as a last resort form of communications in case the portable radios lose connectivity with the infrastructure. This allows the users to communicate directly with each other without the use of the infrastructure. For industrial and government users talking in direct mode, while shorter in range and therefore limited in the number of subscribers that is communicated with, having some limited communications is better than none at all. Higher power output levels increases the reliability of the communications between the radios since the higher power level overcomes the signal path loss better in many environments.

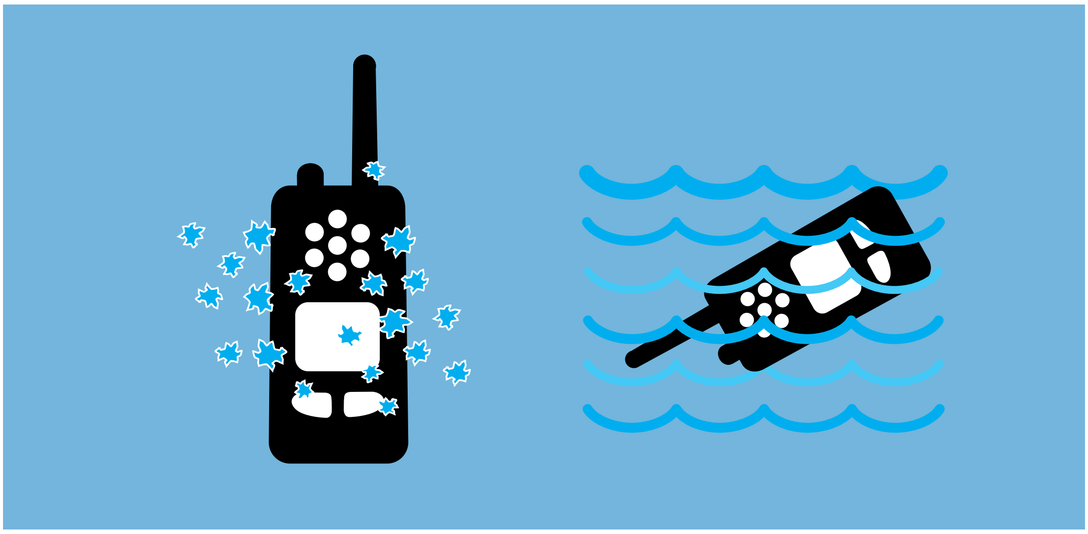
Cellphones don't have a direct mode feature. Why? Because there must be a way to charge for the airtime usage. The infrastructure tracks the minutes used so that the cellphone user can be billed properly. Direct mode bypasses the infrastructure. If a cellphone user used direct mode, there would be no way to track the airtime usage for billing purposes. Also, the very low power levels of cellphones further limits the distance of a direct mode operation, making it an impractical feature for low power devices.

Higher power output levels have one major design consequence and impact on product design – the need for high power amplifiers (PAs), which are larger in size. Conversely, smaller power output devices can use smaller size power amplifiers. The larger size of the PA causes the internal design of the portable radio to be limited in how much it can shrink in overall size.

In addition to the high power PAs, the frequency band also impacts the size of the components inside the radio. A VHF radio has longer wavelengths than an 800 MHz radio. The VHF components and hybrids inside the radio tend to be larger than 800 MHz components, pushing the radio towards larger sizes. Cellphones are at 850 MHz or higher, allowing for much smaller frequency-sensitive components.

Another interesting impact of high power PAs is that it also requires a larger heat sink for dissipating the heat that is generated by the higher power PA. The larger heat sink drives a larger physical form factor, which also adds to the weight, of the subscriber device. With cellular, the smaller power output generates less heat, thereby allowing for a smaller heat sink…again, up to a point. Proper heat dissipation is critical for the safe usage of the device. Some poor cellphone designs that don't have a good heat dissipation design will overheat during a long phone call. In other words, a poorly mechanically-designed cellphone will get super-hot in your hand during a long phone call. The consequence of poor heat dissipation is a shorter life of the PA. The device will fail sooner.

Unlike cellphones that operate at 0.6W, portable two-way radios operate in the 1-5W range. Because of the higher power levels, the two-way radios must be designed to higher RF performance specifications than cellphones. The receiver must be able to operate next to a much higher power transmitter inside a compact handheld housing. The two-way radio receiver must still maintain a high level of sensitivity in order to work effectively in a high power RF environment. Shielding and receiver designs contribute to better receiver performance and intermodulation (IM) rejection, and this can also impact the radio size. Designing to excellent receiver specifications, while keeping the radio as small as possible, is one of the toughest engineering challenges for RF design engineers and mechanical engineers. Once accomplished though, the high quality RF specifications of the portable radios will impact the overall infrastructure design for coverage. A high performance radio can help to lower the number of infrastructure sites.



In addition to the higher power requirement for a high-power power amplifier, most two-way radio subscribers also have another high power requirement – the loudspeaker. Two-way radios are found in many industrial environments that are high noise or have a lot of background noise. Unlike cellphones where users put the device directly on their ear, two-way radios use a loudspeaker that must be able to operate in loud environments. Loudspeakers require higher amperage to drive the speaker element to create the appropriate audio sound pressure for the user to hear the receive audio above the noisy environment. The higher amperage requirements for a loudspeaker require a larger battery requirement, which impacts the size of the radio. The loudspeakers used in two-way radios are designed to be significantly louder than cellphone loudspeakers; cellphone loudspeakers are usually designed for conference call applications inside an office environment, and are not usually adequate for use on-the-street or inside a moving car. The loudspeaker itself may also be larger in diameter to provide the proper sound pressure (and therefore sound volume), which requires the size of the radio to be at least as wide as the speaker.

Operating in rugged, highly industrialized, and possibly hazardous environments, two-way radios require much thicker housings, stronger metal frames and critical sealing from hazardous environments in order to work under such extreme conditions. Industrial design and operating requirements constrain the radio design to a slightly larger physical form factor, resulting in increased weight, than commercial-grade products. Consumer products and commercial-grade products, such as cellphones and commercial-grade two-way radios, are not designed with these kinds of considerations, so their mechanical designs allow for smaller, thinner, lighter housing designs. The difference is clear: try dropping your cellphone a few times in your office. It will break. Ruggedized industrial-grade two-way radios do not break under normal conditions in industrial environments.

If the radio is designed to be submersible (yes, actually going under water!), then the mechanical design must also be made slightly larger to cater for special internal sealing in every possible area of water entry. Making a radio that is submersible or workable in a pressurized water environment, like fire suppression operations, require more rigorous sealing against water pressure rather than just water entry. This requires special silicon sealing, ultrasonic welding, and high strength bonding materials. All of this requires additional space to add all of this for a good, tight seal.

Another factor keeping the radios from shrinking further are the customer demands for more unique features that cellphones don't have. For example, two-way radios can be equipped with government-grade encryption for voice transmissions that require the highest levels of security. This kind of requirement generally requires hardware encryption circuits, and this adds more circuitry and hardware inside the radio. If cellphones had to meet this kind of sophisticated user requirement, cellphones would be bigger than they are today. Indeed, the more ruggedized the radio is required to be, the larger and heavier the mechanical design of the housing must be for the product. There are a few ruggedized cellphones in the market today and they are larger and bulkier than the majority of cellphones on the market.

Market demands for two-way radios to have higher processing power also drive manufacturers to put more electronics into the radio. A modern digital two-way radio today has more processing power and more features than a consumer-grade digital cellphone.

A very ironic scenario today is that the two-way radio electronics may actually be small enough today that the physical form factor might actually be too small for some operational environments! In other words, some operational environments may require a physically larger two-way radio size in order for the user to operate it properly. For example, fireman must wear protective gloves to protect themselves from heat, fire, chemicals, etc., while fighting a fire and cannot remove their gloves inside the hazardous environment to operate the radio. They must be able to operate the radio with a gloved hand. If the radios are too small, they will not be able to operate the radio properly with a gloved hand. So the radio must have large enough knobs and pushbuttons for a gloved hand to be able to operate it. It must also be big enough to fit in the gloved hand. Too small a form factor makes it difficult to handle and easy to drop. Besides the fire service, others users who require a larger sized radio for their operational environment include motorcycle police officers, the military, SWAT teams, oil refinery workers, chemical plant workers, HAZMAT workers, and anyone working outdoors in harsh cold winter conditions.

More recently, interoperability requirements across frequency bands have driven the creation of new multi-band radios, where a single radio can operate in two or more frequency bands. The new multi-band radios are larger because it must contain two or three separate transceivers inside the housing. Also driving a slightly larger housing is the additional filtering and shielding between the transceivers in order to keep the different transceivers from interfering with each other. If proper shielding is not designed in, the potential interference will degrade some of the RF performance characteristics and specifications of the radio.

"TALK TIME" VS. "TRANSMIT-RECEIVE-STANDBY"

In the cellular world, one of the cellphone specifications is "talk time", which is how long a cellphone user can talk to someone, measured in minutes, with the standard battery. In the two-way radio world, "talk time" doesn't work. In the cellular world, a cellular call is a point-to-point call. Talk time is simply the summation of all of the individual point-to-point calls that can be made using the cellphone. The reason why it can be a simple summation is because the cellphone user is either using the cellphone or not. It has only two states: in-use (call is on) or standby (no call).

Two-way radio is a true point-to-multipoint device, where the radio has three states: in-use (radio user is transmitting), receiving a call (radio user is listening), and standby (no call in progress). One of the notable differences between two-way radio and cellular is that the non-standby states are truly separate states. In cellular, when there is a call, both the transmitter and receiver are working during the full-duplex call. The cellphone user is actually listening (receiving) and talking (transmitting) at the same time with the other person on the other end of the call. A 5-minute cellphone call is 5 minutes in total of both transmit and receive because there is only 1 call going on. The majority of the battery power consumption is while the cellular transmitter is on. So the usefulness of the cellphone can be measured by how long the cellphone can be used (transmitting) with the given battery.

Conversely, the two-way radio user doesn't have to talk (transmit) on every received message. Because of the group call nature of communications, the radio user may receive (hear) a lot of messages that are not specifically for the radio user, but the radio user still needs to monitor the activities. For example, a two-way radio user may hear (receive) 30 messages within 1 hour, but only need to respond (transmit) to 3 of those messages. Assuming that each message lasts only 2 seconds each, then the radio is transmitting only 6 seconds (3 messages x 2 seconds each) in total, receiving for 60 seconds (30 messages x 2 seconds each), and in standby mode for the rest of the hour that the radio is not transmitting or receiving (3600 seconds – 60 seconds receiving – 6 seconds transmitting = 3534 seconds). This gives us the cycle time of the two-way radio user (transmit-receive-standby): 6-60-3534 secs or 0.167-1.667-98.167%. Most two-way radio cycle times are specified using a 5-5-90% cycle time assumption, where there is a 5% transmit, 5% receive, and 90% standby. The 5% transmit, 5% receive scenario doesn't mean that for every 1 receive message that there is 1 transmit message of equal duration, although it is possible. It is also possible that the 5% receive is spread out across the 1 hour in many short messages, while the 5% transmit could be from 1 very long transmission within that same hour. The transmit-receive-standby cycle time is determined by how the organization communicates, how the individual radio user manages his/her communication, the type of work activity, the criticality and urgency of the call, and how unique each message is. The transmit-receive-standby cycle time is a more useful way to measure and compare two-way radio specifications and performance than just simply "talk time". It also provides a common basis to which all two-way radios perform in power consumption.

If the radio users exceed the 5-5-90% cycle time, then a high-capacity battery may be required in order to meet a full 8-hour work shift. A high-capacity battery will add more weight and size to the portable radio. Indeed, some system owners will buy larger batteries that go beyond an 8-hour shift to plan for emergencies and disasters. This is the case of "better to have it and not need it" rather than "needing it and not having it". This is about being prepared.

FUTURE DESIGNS

The good news is that portable two-way radio size has been shrinking over the past three decades. Over time, two-way radios are becoming more powerful in processing power as well. Since the introduction of microprocessors and software, two-way radios have made significant gains in features and functions, more rapidly than the physical size improvements. This trend has shown no signs of stopping. We can expect that portable two-way radios will continue to advance in features and functions.

As technology advances in many other industrial areas, those advancements will find its way into two-way radio design. Future two-way radio size reductions depend on technology advancements in many other areas. Specifically, semiconductor miniaturization technology is required to make smaller components, like the power amplifiers, microprocessors, and chipsets. Battery technology must also advance, in order to create lighter weight batteries, yet still be able to provide the proper amperage while being safe. Metal and metallurgy technology must also evolve to discover new lighter weight materials that have better heat dissipation, while maintaining its strength. Materials technology will also have to advance to create lighter, yet remain strong, plastics for housings and sealing.

Many of the technology breakthroughs in the above areas usually go into consumer products first, for two reasons:

1) On the initial introduction of the new products based on the new technology, the specifications tend to be targeted to consumer or commercial-grade specifications, i.e., 0 to 50° C, because it's easier to meet. It is only through refinements and additional research & development where products with more industrialized specifications, i.e., -30 to +60° C, are created later, because the industrial specifications are much harder to achieve.

2) The component manufacturers will usually sell into the consumer and commercial-grade product manufacturers first since there are significantly higher volumes in those markets. This will give a faster financial rate of return to those component manufacturers, as opposed to the industrial products, where the volume of components are less than the consumer and commercial product market.

Because of competition, two-way portable radio manufacturers do try to make the smallest, lightest, and robust product possible, and will use the most up-to-date technologies in creating the best possible portable two-way radio product. The manufacturer who spends the most in R&D is usually the one that will lead the market with the most technologically advanced portable radio product.

The proliferation of attractive consumer products is also affecting industrial designs, where color and attractive graphical user interfaces have now crept into the portable radio designs.

SUMMARY

Two-way radios are gaining popularity globally. In the US and Western Europe, where two-way radios have been used since the 1940's, professional users have always understood that two-way radios are always larger than cellphones. In the rest of the world, where cellphone popularity is more prevalent than two-way radio and was more widely deployed ahead of two-way radio, the size expectation for personal communication devices has been set by cellphones. It is hoped that this white paper has answered the question of why portable two-way radios are larger than cellphones. The basis for current two-way radio design is driven by end-user operational requirements, the environment in which two-way radio must be used in, and the limits of technology.

As a leader in two-way radio technology and winner of many technical design & innovation awards, Motorola continues to invest in a wide variety of supporting technologies that contribute to the next generation of digital two-way radio subscribers. Over many years, Motorola has led the two-way radio development with ever-increasing power and capabilities, where a seemingly simple, unsophisticated product has now evolving into an advanced intelligent device that will one day allow for the convergence of voice, data, and video that will support the various communications functions of integrated command & control, workforce mobility, video security, interoperability, and maybe one day even as a extension of a mobile broadband network.

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