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Introduction by the Associate Editor

My engineering colleague, Karl-Arne Markström of the Swedish URSI committee, and I want to present an 80-year-old innovation for a very relevant application of today, made by two persons outside of the radio-science community. One of them can definitively be presented in "Women in Radio Science."

Some inventions have been made well ahead of their time and by the "wrong" people. Frequency-hopping spread spectrum is a very good example of this. Hedy Lamarr and George Antheil were professionals in show business, but they both had intellectual capacity, knowledge, and experiences that enabled them to think outside the box in order to be able to contribute to solve the problem of secret communications. Their still quite mechanical method, which is described below by Karl-Arne, required some advances in technology development in order to fulfill its potential in relation to Wi-Fi and Bluetooth applications of today.

Hedy Lamarr (Figure 1) was the artist's name of Hedwig Kiesler, born in Vienna in 1914. From when she was a young girl, she wanted to be an actress. She succeeded in her goal, becoming a famous movie star in Europe. Thanks to the #metoo movement, we recently have come to understand that young women are very vulnerable in the film industry. In the 1930s, a marriage hopefully gave some protection against such abuse. When she was very young, Hedy married Fritz Mandl, a rich arms manufacturer in Austria. While participating as a companion in Mandl's business meetings, she got a good insight into military technology.

In the late 1930s, Hedy moved to Hollywood, since her Jewish background made her life insecure in Europe. Both her professional and private life was spectacular in a way that we today would not react so much to. Hedy was also interested in science and technological development, which did not fit so well with the 1940s image of a female movie star, who was expected to concentrate on being attractive.

George Antheil was born in 1900 in an industrial district of Trenton, New Jersey. He was a vivid child and loved to play piano. He was very talented and became a popular concert pianist, composer, and author, active in Berlin, Paris, and Hollywood. He composed both symphonies and film music. The experiments for his most famous composition, "Ballet Mécanique," to synchronize many self-playing pianos gave him useful experience for the coming innovation.

Hedy Lamarr and George Antheil were not the most obvious inventors. They were both famous for something else: being hard-working people and having a good chemistry between them. Hedy was especially concerned about what was happening in her former homeland after

Figure 1. A photograph of Hedy Lamarr for the film, *The Heavenly Body*.

Hitler's takeover. From her time with arms dealer Mandl, she knew how torpedoes worked, and George had experience about the synchronization problem. When the need for secret communications became an urgent issue, Hedy and George started to brainstorm on how to solve the problem.

Their approach could be described as multidisciplinary, due to their different competences. They employed both a university professor in Electrical Engineering from Caltech, and the attorney firm of Lyon and Lyon, which specialized in patents, to produce a very competent patent for the "Secret Communication System" [1]. At the same time, they probably stepped into somebody else's territory.

Walters [1] referred to an event during the war where a commanding officer in the US Navy rejected the use of the patent and caricatures it when he learned who was behind it. To the contrary, some ten years later, when the US Navy contracted the design of a secure sonobuoy system from the Hoffman Corporation, a copy of the patent was provided. The person in charge at Hoffman assumed that "it was existing secret technology devised by some clever electrical engineer working under a Navy contract" [1].

Hedy passed away in the year 2000, and George in 1959, both unfortunately before the time when the full potential of their innovation could be realized. In 2014, they were inducted into the National Invertors Hall of Fame, which honors the people responsible for the great technological advances that make human, social, and economic progress possible.

Reference

1. R. Walters, *Spread Spectrum: Hedy Lamarr and the Mobile Phone*, www.robsbookshop.com, 2014.

The Invention by Hedy Lamarr and George Antheil of Frequency-Hopping Spread-Spectrum Secret Communications

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Already before WW1, the general principles of using frequency agility to avoid detection and jamming had been proposed and actually used on a small scale. However, the limitations of the radio transmitters and receivers of the day made it impractical to implement systems that rapidly changed frequencies on a larger scale.

Remote-controlled flying bombs, torpedoes, and other unmanned craft were a common discussion topic in military circles during the pre-WW2 years, and some radical thinkers predicted their use in a coming war. However, a common concern was the relative ease of jamming or sending false remote-control signals to such weapons, which made the "Powers That Be" somewhat skeptical about their introduction and use. It was in this context that the invention by Lamarr and Antheil can be seen. When their application for US Patent 2,292,387, "Secret Communication System," was filed in June 1941, war had been raging in Europe for almost two years, and many saw it as only a matter of time before the United States was to be drawn into the conflict in one way or another.

Hedy Lamarr had befriended Howard Hughes, famous aviator and film mogul, who had a keen interest in technology and introduced her to commonly discussed matters of the day. It is very likely that she became part of discussions about "secret weapons," and she decided to make a contribution.

Here enters the musical – more specifically, pianist – background of George Antheil. The self-playing piano was an early example of a "programmable mechanism," somewhat in line with the punch-card-programmable Jacquard loom, and in a broader context, the Babbage "Analytical Engine." Punch cards had also been used for decades for accounting and tabulating-machine purposes.